Developing and Evaluating Effective Interventions to Reduce Healthcare-Associated Infection in A Resource-Limited Hospital in Thailand

Thesis

How to cite:

For guidance on citations see FAQs.

© 2017 The Author

https://creativecommons.org/licenses/by-nc-nd/4.0/

Version: Version of Record

Link(s) to article on publisher’s website:
http://dx.doi.org/doi:10.21954/ou.ro.0000d7f3

Copyright and Moral Rights for the articles on this site are retained by the individual authors and/or other copyright owners. For more information on Open Research Online’s data policy on reuse of materials please consult the policies page.

oro.open.ac.uk
Developing and Evaluating Effective Interventions to Reduce Healthcare-associated Infection in A Resource-limited Hospital in Thailand

Maliwan Hongsuwan
Affiliated Research Centre Programme
Mahidol Oxford Tropical Medicine Research Unit

A thesis submitted for the degree of

Doctor of Philosophy

2018 Apr
Examiners

- Professor Jacqueline Reilly, Professor of Infection Prevention and Control, School of Health and Life Sciences, Glasgow Caledonian University

- Professor Alison Holmes, Professor of Infectious Diseases, Faculty of Medicine, Department of Medicine, Imperial College London

**Day of the defense:** 4 Oct 2017
Abstract

The burden of disease due to hospital-acquired infections in developing countries is poorly quantified. Moreover, hand hygiene compliance (amongst the most effective control measures) is often low and high quality research into how to improve it is largely lacking outside high income settings.

I aimed to: 1) describe the burden and trends in healthcare associated infections in Northeast Thailand; 2) investigate knowledge and beliefs amongst healthcare workers in a tertiary hospital in Northeast Thailand about hand hygiene and identify obstacles to improving it; 3) evaluate an intervention to improve hand hygiene compliance in this hospital based on World Health Organization guidelines.

To address the first aim, a retrospective study was conducted using data from 10 provincial hospitals in Northeast Thailand (2004-2010). This demonstrated a high and increasing incidence of hospital-acquired and healthcare-associated bacteraemia, an increasing proportion of extended spectrum beta-lactamase -producing isolates, and high associated mortality.

To address the second aim, a prospective study was conducted using qualitative and quantitative methods. This found that hand hygiene compliance was poor and differed markedly among categories of healthcare workers. Obstacles to good hand hygiene behaviour included intra-personal, inter-personal, and institutional factors.

The third aim was addressed with a cluster-randomized trial to evaluate a multimodal intervention. The intervention was associated with small increases in hand hygiene compliance (OR 1.12; 95% CI 1.01 to 1.24, p = 0.027), though lack of adherence to the intervention was a major problem. Larger improvements were seen in some units (obstetrics and gynecology: OR 3.96; 95% CI 1.88 to 8.31,
p < 0.001) and for some types of opportunities (before patient contact: OR 1.72; 95% CI 1.32 to 2.25, p < 0.001).

The findings show that improvements in hygiene are possible, but multiple organizational factors need to be addressed to achieve acceptable hand hygiene levels in this setting.
Acknowledgements

First of all, I would like to thank my supervisor, Dr. Ben Cooper, for your constant support and providing me several opportunities to learn and develop me to be a PhD student then a researcher. I would like to thank you Dr. Direk Limmathuotsakul for your encouragement and constant supports. My sincere is reserved for Professor Nicholas P. J. Day, main supervisor for your guidance, feedback and helpful advice in this research. I received many things during their supervision; they do not only support me on my study but also help me to overcome various obstacles, to introducing me to a network of great people.

I also would like to give thanks to Ajarn. Vanaporn Wuthiekanun, my third party monitor, for providing kind advices and supports through my PhD life, with love and encouragement whenever I feel terribly depressed. I gratefully acknowledge to Dr. Stuart Blacksell for helping me on the Open University process and documents from the beginning of my PhD program until the last day.

I would also like to thank my kind colleagues at Microbiology Ubon Ratchathani, Mahidol Oxford Tropical Medicine Research Unit (MORU), for their technical and social supports. A big thank you to Mathematical and Economic Modelling department, MORU and Infection control team at the hospital site for their help and support in conducting this research. Additionally, I would like to say thank you to all participants who volunteered to be part of this study.

Finally, I would like to thank my family and friends for their encouragement, love and support for my long road to achieving a PhD.
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>i</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>iii</td>
</tr>
<tr>
<td>List of Contents</td>
<td>iv</td>
</tr>
<tr>
<td>List of Figures</td>
<td>xii</td>
</tr>
<tr>
<td>List of Tables</td>
<td>xiv</td>
</tr>
<tr>
<td>List of Abbreviations</td>
<td>xvii</td>
</tr>
<tr>
<td>List of Publications</td>
<td>xviii</td>
</tr>
<tr>
<td>1. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Background</td>
<td>1</td>
</tr>
<tr>
<td>1.1.1 Healthcare-associated infection (HCAI)</td>
<td>1</td>
</tr>
<tr>
<td>1.1.2 Hand hygiene</td>
<td>2</td>
</tr>
<tr>
<td>1.1.3 Intervention to promote hand hygiene</td>
<td>3</td>
</tr>
<tr>
<td>1.2 Research aims</td>
<td>4</td>
</tr>
<tr>
<td>1.3 Contribution of thesis</td>
<td>5</td>
</tr>
<tr>
<td>1.4 Outline of thesis</td>
<td>6</td>
</tr>
<tr>
<td>2. Literature Review</td>
<td>7</td>
</tr>
<tr>
<td>2.1 Healthcare associated infection</td>
<td>7</td>
</tr>
<tr>
<td>2.1.1 What are healthcare-associated infections and what is the standard terminology?</td>
<td>7</td>
</tr>
<tr>
<td>2.1.2 Transmission of healthcare-associated infections</td>
<td>9</td>
</tr>
<tr>
<td>2.1.3 Impact of healthcare-associated infections</td>
<td>12</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>2.2</td>
<td>Infection prevention and control</td>
</tr>
<tr>
<td></td>
<td>2.2.1 Aim of infection control</td>
</tr>
<tr>
<td></td>
<td>2.2.2 Infection control guidelines</td>
</tr>
<tr>
<td></td>
<td>2.2.3 Standard precautions</td>
</tr>
<tr>
<td></td>
<td>2.2.4 Surveillance of healthcare-associated infection</td>
</tr>
<tr>
<td>2.3</td>
<td>Hand hygiene</td>
</tr>
<tr>
<td></td>
<td>2.3.1 Relationship between hand hygiene and healthcare associated</td>
</tr>
<tr>
<td></td>
<td>infection</td>
</tr>
<tr>
<td></td>
<td>2.3.2 Hand hygiene practice among healthcare workers</td>
</tr>
<tr>
<td></td>
<td>2.3.3 Factors influencing adherence to recommended hand hygiene</td>
</tr>
<tr>
<td></td>
<td>practices</td>
</tr>
<tr>
<td>2.4</td>
<td>Behaviour change</td>
</tr>
<tr>
<td></td>
<td>2.4.1 Behavioural consideration on hand hygiene</td>
</tr>
<tr>
<td></td>
<td>2.4.2 What is a behaviour change intervention?</td>
</tr>
<tr>
<td></td>
<td>2.4.3 Applying behaviour change theory to improve hand hygiene</td>
</tr>
<tr>
<td></td>
<td>behaviour</td>
</tr>
<tr>
<td>2.5</td>
<td>Intervention to improve hand hygiene with recommendation of World</td>
</tr>
<tr>
<td></td>
<td>Health Organization</td>
</tr>
<tr>
<td></td>
<td>2.5.1 The multimodal strategy</td>
</tr>
<tr>
<td></td>
<td>2.5.2 My five moments</td>
</tr>
<tr>
<td></td>
<td>2.5.3 Applying the WHO strategy in healthcare settings</td>
</tr>
<tr>
<td>2.6</td>
<td>The stepped wedge cluster randomized trial</td>
</tr>
<tr>
<td></td>
<td>2.6.1 What is the stepped wedge cluster randomized trial?</td>
</tr>
<tr>
<td></td>
<td>2.6.2 Study rationale</td>
</tr>
<tr>
<td></td>
<td>2.6.3 The stepped wedge cluster randomized trial in health behaviour</td>
</tr>
<tr>
<td></td>
<td>research</td>
</tr>
</tbody>
</table>
3. Burden of hospital-acquired and healthcare-associated infections in a resource-limited hospital setting

3.1 Introduction

3.2 Materials and Methods
   3.2.1 Study population
   3.2.2 Study design
   3.2.3 Ethical review and study permissions
   3.2.4 Data collection
   3.2.5 Definitions
   3.2.6 Statistical analysis

3.3 Results
   3.3.1 Incidence of HAB and HCAB
   3.3.2 Demographic risk factors for HAB and HCAB
   3.3.3 Pathogenic organisms associated with HAB and HCAB
   3.3.4 Mortality associated with HAB and HCAB

3.4 Discussion

3.5 Conclusions

4. Application of the theoretical domain framework for behaviour change to explore noncompliance in hand hygiene behaviour among hospital healthcare workers

4.1 Introduction

4.2 Methods
   4.2.1 Study population
   4.2.2 Study design
   4.2.3 Ethical review and study permissions
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2.4 Study Procedure</td>
<td>67</td>
</tr>
<tr>
<td>4.3 Results</td>
<td>81</td>
</tr>
<tr>
<td>4.3.1 Sample characteristics</td>
<td>82</td>
</tr>
<tr>
<td>4.3.2 Current knowledge about hand hygiene</td>
<td>83</td>
</tr>
<tr>
<td>4.3.3 Current hand hygiene practices</td>
<td>86</td>
</tr>
<tr>
<td>4.3.4 Perceived barriers for non-compliance with hand hygiene</td>
<td>90</td>
</tr>
<tr>
<td>4.3.5 Current beliefs about hand hygiene behaviour</td>
<td>91</td>
</tr>
<tr>
<td>4.3.6 Summary of relevant domain findings by applying the TDF</td>
<td>92</td>
</tr>
<tr>
<td>4.3.7 Mapping domain finding to the Behaviour Change Wheel’s COM-B system</td>
<td>113</td>
</tr>
<tr>
<td>4.4 Discussion</td>
<td>117</td>
</tr>
<tr>
<td>4.4.1 Key findings</td>
<td>117</td>
</tr>
<tr>
<td>4.4.2 Comparing study results with other studies</td>
<td>117</td>
</tr>
<tr>
<td>4.4.3 Theoretical implications</td>
<td>119</td>
</tr>
<tr>
<td>4.4.4 Practical implications</td>
<td>119</td>
</tr>
<tr>
<td>4.4.5 Strengths, limitations and future directions</td>
<td>120</td>
</tr>
<tr>
<td>4.5 Conclusions</td>
<td>120</td>
</tr>
<tr>
<td>5. Impact of a multimodal hand hygiene improvement intervention</td>
<td>121</td>
</tr>
<tr>
<td>5.1 Introduction</td>
<td>121</td>
</tr>
<tr>
<td>5.2 Methods</td>
<td>123</td>
</tr>
<tr>
<td>5.2.1 Participants and Setting</td>
<td>123</td>
</tr>
<tr>
<td>5.2.2 Ethics statements</td>
<td>124</td>
</tr>
<tr>
<td>5.2.3 Study design</td>
<td>125</td>
</tr>
<tr>
<td>5.2.4 Study Duration</td>
<td>125</td>
</tr>
<tr>
<td>5.2.5 Study Intervention</td>
<td>126</td>
</tr>
<tr>
<td>5.2.6 Study Procedures</td>
<td>130</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>--------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>5.2.7 Data Collection</td>
<td>135</td>
</tr>
<tr>
<td>5.2.8 Outcome measurements</td>
<td>136</td>
</tr>
<tr>
<td>5.2.9 Statistical considerations</td>
<td>136</td>
</tr>
<tr>
<td>5.3 Results</td>
<td>139</td>
</tr>
<tr>
<td>5.3.1 Study flow</td>
<td>139</td>
</tr>
<tr>
<td>5.3.2 Number analyzed</td>
<td>140</td>
</tr>
<tr>
<td>5.3.3 Hand hygiene compliance observations</td>
<td>141</td>
</tr>
<tr>
<td>5.3.4 Hand hygiene compliance by “My five moments for hand hygiene”</td>
<td>157</td>
</tr>
<tr>
<td>5.3.5 Effectiveness of a multimodal hand hygiene improvement strategy</td>
<td>160</td>
</tr>
<tr>
<td>5.4 Discussion</td>
<td>161</td>
</tr>
<tr>
<td>5.4.1 Key findings</td>
<td>161</td>
</tr>
<tr>
<td>5.4.2 Comparison of findings with other studies</td>
<td>162</td>
</tr>
<tr>
<td>5.4.3 Strengths, limitations and future directions</td>
<td>163</td>
</tr>
<tr>
<td>5.5 Conclusions</td>
<td>165</td>
</tr>
<tr>
<td>6. Discussion and conclusions</td>
<td>166</td>
</tr>
<tr>
<td>6.1 Substantive discussion</td>
<td>166</td>
</tr>
<tr>
<td>6.2 Implications of the research findings</td>
<td>171</td>
</tr>
<tr>
<td>6.3 Limitations of this thesis</td>
<td>173</td>
</tr>
<tr>
<td>6.4 Strengths of this thesis</td>
<td>174</td>
</tr>
<tr>
<td>6.5 Future research directions</td>
<td>174</td>
</tr>
<tr>
<td>6.6 Conclusions</td>
<td>175</td>
</tr>
<tr>
<td>References</td>
<td>177</td>
</tr>
<tr>
<td>Appendices</td>
<td>198</td>
</tr>
<tr>
<td>A Chapter 2 Supplementary</td>
<td>199</td>
</tr>
</tbody>
</table>
B Chapter 3 Supplementary

B.1 Ethical documents

B.2 List of participating hospitals

B.3 Location of participating hospitals

B.4 Trend in hospital-acquired bacteraemia and healthcare-associated bacteraemia in ten provincial hospitals in Thailand

B.5 Top five most common isolates causing primary episode of hospital-acquired bacteraemia and healthcare-associated bacteraemia by year in northeast Thailand between 2004 and 2010

B.6 Top five most common isolates causing primary episode of hospital-acquired bacteraemia and of healthcare-associated bacteraemia by provincial hospital in northeast Thailand between 2004 and 2010

B.7 Proportions of ESBL-producing *Escherichia coli*, ESBL-producing *K. pneumoniae*, and MRSA as a cause of hospital-acquired bacteraemia over time in northeast Thailand

B.8 Trend in overall proportion of ESBLs producing *Escherichia coli* causing hospital-acquired bacteraemia and causing and healthcare-associated bacteraemia in provincial hospitals in Thailand

B.9 Proportions of ESBL-producing *Escherichia coli*, ESBL-producing *K. pneumoniae*, and MRSA as a cause of healthcare-associated bacteraemia over time in northeast Thailand

B.10 Trend in overall proportion of ESBLs producing *Klebsiella pneumoniae* causing hospital-acquired bacteraemia and causing and healthcare-associated bacteraemia in provincial hospitals in Thailand

B.11 Trend in overall proportion of methicillin resistant *Staphylococcus aureus* causing hospital-acquired bacteraemia and causing and healthcare-associated bacteraemia
associated bacteraemia in provincial hospitals in Thailand

C Chapter 4 Supplementary

C.1 Ethical documents
C.2 Theoretical Domains Framework and example questions
C.3 Participants of focus groups according their departments
C.4 Descriptive data of semi-structured interview participants (n = 5)
C.5 Summary of current knowledge of hand hygiene from participants
   (N = 1,582)
C.6 Summary of self-reporting on hand hygiene compliance from
   participants (n = 1,126)
C.7 Summary on hand hygiene performed by all opportunities for requiring
   hand hygiene practices (n = 3,564)
C.8 Summary on hand hygiene compliance of all healthcare workers (n = 364)
C.9 Internal consistency of domains (α) and the distribution of response on
   current beliefs on hand hygiene (N = 1,582)
C.10 Correlations between theoretical domains about hand hygiene among
    participants (N = 1,582)
C.11 Correlations of performed hand hygiene practice between theoretical
    domains among participants (n = 364)

D Chapter 5 Supplementary

D.1 Ethical documents
D.2 The intervention “Menu”
D.3 Description of assessment of inter-rater reliability
D.4 Descriptive statistics for characteristics and covariates in the study by
   hand hygiene events vs. all observed events [n]
D.5  Descriptive statistics by observed opportunities [n] for characteristics and covariates in the study  264

D.6  Summary of characteristics of all study wards  266

D.7  Hand hygiene compliance of study wards  272

D.8  Descriptive statistics for characteristics and covariates in the study by observed HCWs [n]  276

D.9  Characteristic of hand hygiene compliance by the variables during before intervention  277

D.10 Characteristic of hand hygiene compliance by the variables and during after intervention  279

D.11 Characteristic of hand hygiene compliance by the variables during overall intervention  281

D.12 Compliance with hand hygiene at before and at after intervention  283

E  Publications arising directly from the thesis  285
## List of figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Study framework of the thesis: “Developing and evaluating effective interventions to reduce healthcare-associated infection in a resource-limited hospital in Thailand”</td>
<td>5</td>
</tr>
<tr>
<td>2.1</td>
<td>Bacterial contamination and cross-transmission by contaminated hands</td>
<td>11</td>
</tr>
<tr>
<td>2.2</td>
<td>Box-and-whiskers plot showing relative efficacy of different hand hygiene intervention strategies compared with standard of care estimated by network meta-analysis</td>
<td>41</td>
</tr>
<tr>
<td>2.3</td>
<td>Example of a stepped wedge design</td>
<td>43</td>
</tr>
<tr>
<td>3.1</td>
<td>Age- and gender-specific incidence rate of hospital-acquired bacteraemia</td>
<td>54</td>
</tr>
<tr>
<td>3.2</td>
<td>Age- and gender-specific incidence rate of healthcare-associated bacteraemia</td>
<td>55</td>
</tr>
<tr>
<td>4.1</td>
<td>Score of current knowledge (n = 1,582), % hand hygiene compliance by self-reporting (n = 1,126), and % hand hygiene compliance by direct observation (n = 364) by explanatory variables</td>
<td>87</td>
</tr>
<tr>
<td>4.2</td>
<td>Factors and theoretical domains with Cronbach’s alpha (α) and domain loading (N = 1,694) Factor correlation (r) is provided with p values (two-tailed)</td>
<td>115</td>
</tr>
<tr>
<td>5.1</td>
<td>Implementation process summary: the WHO multimodal hand hygiene improvement strategy, the “My 5 Moments for Hand Hygiene” approach, and the step-wise approach</td>
<td>129</td>
</tr>
</tbody>
</table>
5.2 Study phases 131
5.3 Stepped wedge design of phase 2 of the hand hygiene intervention 132
5.4 Timeline of study period for randomisation and implementation 142
5.5 Hand-hygiene compliance in each ward by week 146
5.6 Hand-hygiene compliance in ICU wards and non-ICU wards: intention-to-intervene analysis 152
5.7 Hand-hygiene compliance in ICU wards and non-ICU wards: per-protocol analysis 153
List of tables

2.1 Definition of community-acquired, hospital-acquired and healthcare-associated bacteraemias 9
2.2 Mapping of the Behaviour Change Wheel’s COM-B system to the TDF Domains 24
2.3 Domains in the theoretical domains framework 25
2.4 Constructs in four theoretical domains, illustrating individual, team, and organizational levels based on construct allocations 27
2.5 Steps for developing a theory-informed implementing intervention 30
2.6 Example of application of behaviour change techniques for improving hand hygiene behaviour 33
2.7 The “My five moments for hand hygiene” concept and transmission risks 37
2.8 Description of hand hygiene intervention components 40

3.1 Incidence rate of hospital-acquired bacteremia (HAB) and associated death rate 51
3.2 Cumulative incidence of healthcare-associated bacteremia (HCAB) and associated death rate 53
3.3 Pathogenic organisms isolated from 3,424 patients with primary episode of hospital-acquired bacteraemia (HAB) and 2,184 patients with primary episode of healthcare-acquired bacteraemia (HCAB) 56
4.1 The theoretical constructs used to analyses text data and example questions
4.2 Mapping of the Behaviour Change Wheel’s COM-B system to the TDF Domains
4.3 Constructs in four theoretical domains, illustrating individual, team, and organizational levels
4.4 Characteristics of the study population by demographic in study setting
4.5 Descriptive data for focus group participants (n = 32)
4.6 Summary of hand hygiene performance for all opportunities requiring hand hygiene (n = 3,564)
4.7 Perceived barriers for non-compliance with hand hygiene reported by respondents (N = 1,582)
4.8 Examples of specific beliefs elicited from semi-structured interviews with key informants (n=5) and focus group discussions with representative of each type of healthcare worker (n=32)
4.9 Rotated component matrix of theoretical domains and explained variance of each factor for all participants who completing the questionnaire (N = 1,582)
5.1 Description of the key components of the strategy on the intervention menu
5.2 Power to detect increases in hand hygiene of compliance of 2 or 5% significant at the 5% level as a function of baseline hand hygiene compliance and the intra cluster correlation coefficient
5.3 Descriptive opportunity for hand hygiene by characteristics and covariates in the study
5.4 Descriptive statistics for characteristics and covariates in the study by observed HCWs [n]
5.5 Estimated odds ratios (95% CI) associated with the intervention allowing for effect modification by type of ward in a model excluding potential confounders (intention-to-intervene analysis)
5.6 Estimated odds ratios (95% CI) of hand hygiene compliance associated with the intervention allowing for effect modification by type of ward (per-protocol analysis)

5.7 Estimated odds ratios (95% CI) of hand hygiene compliance associated with the intervention allowing for effect modification by intensive-care unit in a model excluding potential confounders (intention-to-intervene analysis)

5.8 Estimated odds ratios (95% CI) of hand hygiene compliance associated with the intervention allowing for effect modification by intensive-care unit (per-protocol analysis)

5.9 Estimated odds ratios (95% CI) of hand hygiene compliance associated with the intervention allowing for effect modification by department—subgroup analysis (intention-to-intervene analysis)

5.10 Estimated odds ratios (95% CI) of hand hygiene compliance associated with the intervention allowing for effect modification by department—subgroup analysis (per-protocol analysis)

5.11 Estimated odds ratios (95% CI) for hand hygiene compliance associated with the intervention according to hand hygiene opportunity type (intention-to-intervene analysis)

5.12 Estimated odds ratios (95% CI) for hand hygiene compliance associated with the intervention according to hand hygiene opportunity type (per-protocol analysis)

5.13 The intervention implementation by applying multimodal hand hygiene improvement strategy

5.14 Estimated odds ratios (95% CI) for hand hygiene compliance associated with the intervention components
## List of abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABHR</td>
<td>Alcohol-based handrub</td>
</tr>
<tr>
<td>AMR</td>
<td>Antimicrobial resistance</td>
</tr>
<tr>
<td>BCW</td>
<td>Behaviour Change Wheel</td>
</tr>
<tr>
<td>CAB</td>
<td>Community-acquired bacteraemia</td>
</tr>
<tr>
<td>CDC</td>
<td>Centers for Disease Control and Prevention</td>
</tr>
<tr>
<td>CI</td>
<td>Confident interval</td>
</tr>
<tr>
<td>FIT</td>
<td>Feedback Intervention Trial</td>
</tr>
<tr>
<td>HAB</td>
<td>Hospital-acquired bacteraemia</td>
</tr>
<tr>
<td>HCAB</td>
<td>Healthcare-associated bacteraemia</td>
</tr>
<tr>
<td>HCAI</td>
<td>Healthcare-associated infection</td>
</tr>
<tr>
<td>HCW</td>
<td>Health-care worker</td>
</tr>
<tr>
<td>ICN</td>
<td>Infection control nurse</td>
</tr>
<tr>
<td>ICU</td>
<td>intensive care unit</td>
</tr>
<tr>
<td>MDRO</td>
<td>Multidrug resistant organism</td>
</tr>
<tr>
<td>MRSA</td>
<td>Methicillin-resistant <em>Staphylococcus aureus</em></td>
</tr>
<tr>
<td>NHS</td>
<td>National Health Service</td>
</tr>
<tr>
<td>NHSN</td>
<td>National Healthcare Safety Network</td>
</tr>
<tr>
<td>NI</td>
<td>Nosocomial infection</td>
</tr>
<tr>
<td>NICE</td>
<td>National Institute for Health and Care Excellence</td>
</tr>
<tr>
<td>RCT</td>
<td>Randomized controlled trial</td>
</tr>
<tr>
<td>SW-RCT</td>
<td>Stepped wedge cluster randomized controlled trial</td>
</tr>
<tr>
<td>TDF</td>
<td>Theoretical domain framework</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>WHO-S</td>
<td>The WHO Five Multimodal Hand Hygiene Improvement Strategy</td>
</tr>
</tbody>
</table>
List of Publications


Chapter 1

Introduction

1.1 Background

1.1.1 Healthcare-associated infection (HCAI)

A healthcare-associated infection (HCAI) can be defined as an infection occurring in a patient during their care in a hospital or other health-care facility which was not present or incubating at the time of admission to the facility.¹ This definition includes infections which are acquired in the health-care facility but which become apparent only after discharge. It also includes occupational infections among staff of the facility.

HCAIs are a major health problem in both developed and developing countries, and represent a major cause of preventable morbidity and mortality.²⁻⁶ Although HCAIs affect 5-10% of acute-care patients in developed countries, infection rates in developing countries have consistently been found to be much higher.² In addition, mortality due to such infections in developing countries has been found to greatly exceed that in resource-rich settings.²⁻³,⁷

Similar to other developing countries, HCAIs in Thailand are a major health problem and an important cause of death as well as a substantial economic burden due to the cost of treatment and additional length of stay. The point prevalence rate of nosocomial infection (NI) in Thailand was reported to be 6.5% in August 2006 (based on a study of 20 hospitals involving 9,865 patients).⁸ A very similar infection rate was found in the previous survey in March 2001, when the point
prevalence rate of NI (based on 42 hospitals involving 18,456 patients) was 6.4%, and 13.8% of patients with NI died, 6.7% directly due to NI.\[9\]

Applying infection control practices from developed countries (such as patient screening and isolation) to hospitals in developing countries would require substantial investment, although this should, to some degree, be offset by reducing the expense of nosocomial infections. There is, however, evidence that selected, concerted and low-cost interventions are able to greatly reduce the incidence of HCAIs, resulting in improved patient outcomes.\[10, 11\] However, results from a study in a 1000-bed tertiary in the northeast of Thailand found that current hospital infection control guidelines are not fully implemented due, in part, to resource constraints.\[12-14\]

Low compliance to infection control measures is often reported,\[15\] and a recent World Health Organization (WHO) report highlighted a lack of knowledge concerning the control of HCAIs and the epidemiology of important healthcare-associated pathogens in developing countries.\[16\] Developing cost-effective interventions capable of reducing the burden of HCAI requires a detailed knowledge of local conditions, including infection control policies currently in place, and barriers to implementing both existing and enhanced control measures.

1.1.2 Hand hygiene

Health-care worker hand hygiene is widely believed to be the most important activity for the prevention of HCAIs.\[17\] But many observational studies demonstrate poor adherence by health-care workers (HCWs).\[18-20\] Several barriers to appropriate hand hygiene have been reported, including forgetfulness, ignorance of guidelines, insufficient time, high workload and understaffing, and lack of scientific information demonstrating impact of improved hand hygiene on hospital infection rates.\[21-33\]
Recently, behavioural theories have been applied to better understand the reasons for non-compliance with hand hygiene recommendations at the individual and institutional levels. The theoretical domain framework (TDF) is a theory of behaviour change, which provides a useful conceptual basis for exploring and understanding the behaviour-change process and its effect on the health professionals’ behaviour. The framework has been used to assess potential determinants of behavior change with both qualitative and quantitative measurement tools. Ideally, the determinants of targeted behaviour should be identified before designing the intervention. Developing an understanding of factors associated with the targeted behaviour is an important part the process of intervention development. Therefore, before designing an intervention to promote hand hygiene among HCWs, factors associated with non-compliance in hand hygiene behaviour should be considered.

1.1.3 Intervention to promote hand hygiene

The WHO Guidelines on Hand Hygiene in Health Care were launched in 2009 to support healthcare facilities to improve hand hygiene and thus reduce HCAIs. Components of an intervention package include 1) system change, 2) training/education, 3) evaluation and feedback, 4) reminders in the work place and 5) institutional safety climate. The WHO guidelines provides details of strategies to improve hand hygiene by implementing multiple actions to tackle different obstacles and behavioural barriers.

Several studies have attempted to promote hand hygiene by applying WHO guidelines and have reported positive results on improving hand hygiene compliance. But few studies come from developing countries, and only a few studies have evaluated the effectiveness of interventions for improving hand hygiene compliance using strong study designs, and almost all of these have been in high income countries.
The major questions posed by this thesis are as follows:

1. What is the burden of hospital-acquired and healthcare-associated infection in a resource-limited hospital setting?
2. What are the barriers to improving hand hygiene compliance in a resource-limited hospital setting?
3. Is it possible to identify effective methods for improving hand hygiene compliance in resource-limited hospital settings?

1.2 Research aims

Research objectives are as follows:

- To describe the burden of hospital-acquired and healthcare-associated infections in a resource-limited hospital setting
- To identify barriers to improving hand hygiene compliance in a resource-limited hospital setting
- To evaluate the methods for improving hand hygiene compliance in a resource-limited hospital setting

The first aim (performed in 2010) was to quantify the burden of HAI and HCAI. The purpose of this was to provide clear motivation for interventions to reduce this burden.

The second aim (performed in 2010-2011) was to understand the current practice regarding hand hygiene by HCWs, current levels of knowledge, and identify obstacles to improvement. The preliminary results from this aim were used to inform the intervention in the third aim, though more detailed analysis of data collected for this aim was not performed until the last year of thesis, when the intervention study had been completed. It was hoped that this more detailed analysis would help understand why the intervention had worked well in some places, but less well in others.
The third aim (conducted between 2012-2015) was to evaluate an intervention for improving hand hygiene practice among HCWs. The intervention study was developed in 2012, and actually conducted between 2013-2015.

**Figure 1.1:** Study framework of the thesis: “Developing and evaluating effective interventions to reduce healthcare-associated infection in a resource-limited hospital in Thailand”

---

**Study plan**

- **Aim 1**: A retrospective study to describe the burden of hospital-acquired and healthcare-associated infections
- **Aim 2**: A cross-sectional and descriptive study to identify barriers to improving hand hygiene compliance
- **Aim 3**: A prospective stepped wedge trial to evaluate the methods for improving hand hygiene compliance

---

**1.3 Contribution of thesis**

This thesis makes three contributions. The first contribution is to quantify the burden of hospital-acquired and healthcare-associated infections in a resource-limited hospital setting. The second contribution is to apply the theoretical domain framework to identify systematically the obstacles to improving hand hygiene behaviour in a resource-limited hospital, and to develop a deeper understanding of beliefs and perceptions about hand hygiene behaviour. The third contribution is to evaluate an intervention package to improve hand hygiene suitable for resource-limited hospitals.
The overall aim is to generate generalisable knowledge that is of relevance not only to other resource-constrained hospitals in Thailand but which, given the lack of methodologically sound evaluations of the impact of hand hygiene interventions in hospitals in developing countries, also has much wider international significance.

1.4 Outline of thesis

In addition to this introductory chapter, this thesis has five further chapters:

Chapter 2 is a review of the current literature on HCAI, relationship between hand hygiene and HCAIs, hand hygiene behaviour, and interventions to promote hand hygiene.

Chapter 3 addresses the first aim, quantifying the burden of hospital-acquired and healthcare-associated infections in a resource-limited hospital setting.

Chapter 4 addresses the second aim, identifying barriers to improving hand hygiene compliance in a resource-limited hospital setting.

Chapter 5 is concerned with the third aim, to evaluate an intervention intended to improve hand hygiene compliance in a resource-limited hospital setting.

Chapter 6 is a general discussion and summary of findings from this thesis. Implications of the research findings, and strengths and limitation of this thesis are considered. Future research directions are also discussed.
Chapter 2

Literature Review

2.1 Healthcare associated infection

This section will consider: i) what are healthcare associated infections (HCAIs) and what standard terminology is used; ii) transmission of HCAIs; and iii) impact of HCAIs.

2.1.1 What are healthcare-associated infections and what is the standard terminology?

In 1988, The Centers for Disease Control and Prevention (CDC)\(^5^2\) classified surveillance infection data into two types, community acquired and nosocomially acquired infections, and also developed a new set of definitions of nosocomial infections for specific infection sites (e.g. urinary, pulmonary).\(^5^2\)

In 2002, The World Health Organization (WHO)\(^5^3\) decided that what had been called “nosocomial infection” would be referred to as “hospital-acquired infection”. The definition of “hospital-acquired infection” includes infections acquired in the hospital but appearing after discharge, and also occupational infections among staff of the facility.\(^5^3\)

Since 2008, the CDC\(^5^4\) have used the generic term “healthcare-associated infection” instead of “nosocomial infection”, modifying the new definition to “infections that patients acquire during the course of receiving treatment for other conditions within a healthcare setting”. This includes infection that develops in hospital, or a systemic condition resulting from an adverse reaction to an infectious agent(s) or its toxin(s) after 48 hours of hospitalization.\(^5^4\)
In 2011, the National Institute for Health and Care Excellence (NICE) in the United Kingdom began publishing public health guidelines and also defined healthcare-associated infections (HCAIs) to be infections occurring as a direct result of healthcare interventions such as medical or surgical treatment, or from being in contact with a healthcare setting.\textsuperscript{[55]}

Nosocomial or hospital-acquired infection therefore refers to an infection that exists during hospitalization or after discharge. The term healthcare-associated infection is used when the infection is not present before someone has been under medical care, but is present after 48 hours of hospitalization.

Hospital-acquired pathogens with multidrug resistant bacteria are frequently found in patients who have a positive blood culture within 48 hours of hospitalization,\textsuperscript{[56]} which suggests community onset of the infection. Within the last 15 years some researchers have proposed a new class/definition of “healthcare-associated” infection distinct from both community-acquired and hospital-acquired infections for bloodstream infection\textsuperscript{[57-59]} by considering the aetiology (such as the history of exposure to healthcare settings prior to admission) and predisposing conditions. Table 2.1 summaries these classifications of bloodstream infections by Shorr \textit{et al.}\textsuperscript{[59]}

The current study focuses on all infections that are acquired from the healthcare setting (including hospital-acquired and healthcare-associated infections). Therefore the specific term community acquired, hospital-acquired and healthcare-associated infections in this study are modified from Shorr \textit{et al.}\textsuperscript{[59]}
Table 2.1: Definition of community-acquired, hospital-acquired and healthcare-associated bacteraemias, from Shorr et al., 2006[59]

<table>
<thead>
<tr>
<th>Category</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital-acquired bacteraemia</td>
<td>Patients with a first positive blood culture &gt; 2 days from admission</td>
</tr>
<tr>
<td>Healthcare-associated bacteraemia</td>
<td>Patients with a first positive blood culture within 2 days of admission and any of the following:</td>
</tr>
<tr>
<td></td>
<td>● Admission source indicates a transfer from another healthcare facility</td>
</tr>
<tr>
<td></td>
<td>● Prior hospitalization within 30 days</td>
</tr>
<tr>
<td>Community-acquired bacteraemia</td>
<td>Patients who do not meet HAB or HCAB definitions and with the first positive blood culture ≤ 2 days</td>
</tr>
</tbody>
</table>

2.1.2 Transmission of healthcare-associated infections

HCAIs are infections that are not present in the patient at the time of admission to hospital but develop during the course of the stay in hospital.[60] There are two possible sources of the infection. The first source is the bacterial flora of the patient him or herself. This is called endogenous infection or self-infection. The second source is contact with new infective agents outside the patient. This is called exogenous infection or cross-infection.[61] While there is no clinical difference between the endogenous and exogenous infection, the distinction is important from the point of view of epidemiology and prevention.[60]

Healthcare-associated pathogens including multidrug-resistant pathogens can survive on three sources: as part of the bacterial flora of the patient, as part of the bacterial flora of the HCW, and in the environment in the healthcare setting. Some healthcare-associated pathogens, such as Meticillin resistant Staphylococcus aureus (MRSA), can colonise the body of a host (who might be a patient or
HCW) at several different sites.\textsuperscript{[62]} Cross-transmission of healthcare-associated pathogens can occur via contaminated hands where contamination may arise through contact with other patients or contact with the environment.\textsuperscript{[47, 63]}

Pittet \textit{et al} published an evidence-based model for hand transmission during patient care that explained the sequential steps of patient-to-patient transmission of pathogens via HCWs’ hands.\textsuperscript{[63]} The five reported sequential steps are:

\begin{enumerate}
  \item organisms are present on the patient’s skin or have been shed onto fomites in the patient’s immediate environment;
  \item organisms must be transferred to HCWs’ hands;
  \item organisms must be capable of surviving on HCWs’ hands for at least several minutes;
  \item handwashing or hand antisepsis by the HCW must be inadequate or omitted entirely, or the agent used for hand hygiene inappropriate; and
  \item the caregiver’s contaminated hand(s) must come into direct contact with another patient or with a fomite in direct contact with the patient.
\end{enumerate}

\textbf{In summary}, HCW’s hands can act as a vector to carry healthcare-associated pathogens from different sources (other patients, the HCW, the environment) to the patient, which can lead to colonization and subsequently infection. If this understanding is correct, it follows that some HCAIs are preventable by disinfecting HCW hands to break the chain of transmission.

Figure 2.1 presents a visualization of bacterial contamination, and cross-transmission by contaminated hands resulting from failure to clean hands of HCWs.
**Figure 2.1:** Bacterial contamination and cross-transmission by contaminated hands from “WHO Guidelines on Hand Hygiene in Health Care” World Health Organization, 2009, [http://apps.who.int/iris/bitstream/10665/44102/1/9789241597906_eng.pdf](http://apps.who.int/iris/bitstream/10665/44102/1/9789241597906_eng.pdf), accessed December 2016

A Organisms present on patient skin or the immediate environment

B Organism transfer from patient to HCWs’ hands

C Cross-transmission between patient skin and HCWs’ hands

D Failure to cleanse hands results in between-patient cross-transmission
2.1.3 Impact of healthcare-associated infections

As mentioned in the previous section, HCAIs, also referred to as “nosocomial” or “hospital-acquired” infections, are complications of healthcare that lead to increased patient morbidity and mortality\(^\text{[64]}\) and also lead to increased healthcare costs for patients, their insurers and hospitals.\(^\text{[1]}\) Such infections are also an important issue for quality of care in healthcare setting.

The WHO have attempted to summarize the global burden of HCAI from several studies to highlight their importance as a public health problem, but the overall burden remains unknown, in part because of the use of different diagnostic criteria for HCAIs.\(^\text{[1]}\)

The WHO data indicate that hundreds of millions of patients are affected by HCAIs worldwide each year, leading to significant mortality and financial losses for health systems.\(^\text{[1, 64]}\)

In high-income countries, approximately 30% of patients in intensive care units (ICUs) are affected by at least one HCAI. In low- and middle-income countries the frequency of ICU-acquired infection is at least 2–3 fold higher than in high-income countries.\(^\text{[1]}\)

HCAI rates also vary within developing countries.\(^\text{[3]}\) The incidence is reported to be 5-15% of hospitalized patients and can affect 9-37% of those admitted to intensive care units.\(^\text{[1, 64]}\) Several studies conducted in developing countries have reported a wide range of infection rates which are higher than in developed countries while rates of infection in some developing countries, such as Thailand, are not significantly different from developed countries. For instance, a prevalence survey conducted in Thailand in 1988, 1992, 2001 and 2006, shows that HCAIs rates were 11.7%, 7.4%, 6.4% and 6.5 %, respectively,\(^\text{[8]}\) while in some parts of Asia and South Africa rates were higher than 40%.\(^\text{[3]}\)

The difficulty of comparing the reported burden of HCAI in different countries was also addressed in a systematic review on HCAI in developing counties.\(^\text{[3]}\) The main problems come from three key points: the first is uniformity of the definition, the second is that data may not be representative of
the national level (most of the results often come from a single hospital or single ward), and the last is that there are few results from developing countries. Improving surveillance of infection in developing countries is needed to better quantify the burden of HCAI.

**In summary**, HCAIs can result in major costs to patients and the healthcare system, with high impact on patient safety. However, there have been few studies to quantify the burden of HCAI in developing countries. The use of methods to better understand the current situation of HCAI should be considered as one part of infection control in developing countries and given high priority.

### 2.2 Infection prevention and control

This section reviews infection prevention and control measures that can impact on HCAI. There are four parts: i) aims of infection control, ii) infection control guidelines, iii) standard precautions, and iv) surveillance of HCAI.

#### 2.2.1 Aim of Infection control

Infection control is concerned with preventing HCAI, a sub-discipline of epidemiology. Infection control covers the following functions:

i. prevention (e.g. via hand hygiene/hand washing, cleaning/disinfection/sterilization, vaccination),

ii. monitoring/investigation of suspected outbreaks within a health-care setting

iii. intervention i.e. taking action to stop ongoing outbreaks.
2.2.2 Infection control guidelines

Infection control guidelines are the protocols for healthcare practitioners to standardise procedures to help stop the spread of infection. Many guidelines for infection prevention and control are generated and maintained by different organizations around the world such as the Centers for Disease Prevention and Control and the National Healthcare Safety Network (CDC/NHSN), the National Health Service (NHS) hospitals in England, the NICE, and the WHO.

In Thailand, in 1982, the Ministry of Public Health initiated nosocomial infection (NI) controls through infection control guidelines based on the CDC/NHSN guidelines. Implementation of these guideline was tested in participants from 20 hospitals aiming to assess the quality of NI control. The research found that the knowledge, skill and time available for infection control of infection control nurses (ICNs) needed to be improved. Surveillance methods of NI were considered to be not appropriate in many hospitals. The main problems and obstacles for implementation of NI control were the lack of support from administrators and the lack of the ICN post. NI control in regional and provincial hospitals in Thailand needs more support from administrators and more co-operation from medical personnel. Currently in Thailand, local hospital-specific guidelines are generated based upon each hospital’s policy and details of the hospital setting, aiming to develop and implement best practice accounting for local conditions. For example, a university teaching hospital in the northern part of Thailand has developed hand hygiene guidelines as a part of infection control guidelines. These infection control guideline for the hospital were derived from the infection control guidelines of the CDC/NHSN, but with some adaptations to make them suitable for current policy and current practice within the hospital.

In summary, infection control guidelines are important tools to prevent and control HCAI and good infection control depends on the cooperation of all staff. Failure to implement infection control guidelines can lead to increased rates of HCAIs.
2.2.3 Standard Precautions

Standard Precautions aim to protect both staff and patients from infection and apply to all patient care, regardless of confirmed or suspected infection status of the patient, in any setting where healthcare is delivered. The standard precautions include: 1) hand hygiene, 2) use of personal protective equipment (e.g., gloves, gowns, masks), 3) safe injection practices, 4) safe handling of potentially contaminated equipment or surfaces in the patient environment, and 5) respiratory hygiene.

In summary, infection control measures are most effective when Standard Precautions in healthcare setting are applied because undiagnosed or asymptomatic infection is common. Good hand hygiene practice is an essential component of these precautions and considered as one standard part of infection prevention practice.

2.2.4 Surveillance of healthcare-associated infection

Surveillance is defined as “the systematic, on-going collection, collation and analysis of data with timely dissemination of information to those who require it in order to take action.” Such actions are thought to commonly underpin improvements in prevention or control of HCAIs.

Surveillance for HCAIs is normally performed by trained infection prevention and control professionals or hospital epidemiologists. Surveillance, as part of infection prevention and control programs in health care facilities, allows detection of unusually high rates of infection and trends over time. There are two types of measures commonly used as outcome indicators in surveillance: process measures (HCWs’ compliance with hand hygiene) and indicators of adverse events e.g. incidence of healthcare-associated Meticillin-resistant Staphylococcus aureus (MRSA) bacteraemia. Apisarnthanarak et al., recently reviewed the role of infection prevention and control in Asia and highlighted the need for quality improvement for hospitals in Asian-Pacific countries.
Interpretation of HCAI rates can identify areas where improvements to infection prevention and control practices are needed, or evaluate where preventive interventions have been effective in reducing the risk of infection. Because health care settings will have differing priorities for surveillance and resources available to them, case finding may vary from facility to facility.

In summary, many HCAIs are thought to be preventable though implementation of the best infection prevention and control practices. These practices include two key types of surveillance: i) surveillance of HCAI as an outcome measure, and surveillance on the rate of hand hygiene compliance as a process measure. This surveillance facilitates the delivery of high quality health care for patients and a safe working environment for HCWs.

2.3 Hand hygiene

As described earlier, HCWs' hands play a key role in the transfer healthcare-associated pathogens to patients. This section provides information on hand hygiene, and consists of three parts: i) relationship between hand hygiene and HCAI, ii) hand hygiene practice among HCWs, and iii) factors influencing adherence to recommended hand hygiene practices.

2.3.1 Relationship between hand hygiene and healthcare associated infection

Hand hygiene practices among HCWs were first recognized as an effective tool to reduce maternal mortality in the late 1840's in a Vienna hospital by Dr. Ignaz Semmelweis.[77] Since then, the importance of hand hygiene in reducing the number of HCAIs has been highlighted in many studies including observational studies, experimental studies and systematic reviews. An overview of this work is given below.
The WHO reported that at least 20 hospital-based studies of the impact of hand hygiene on the risk of HCAI were published between 1975 and June 2008. Overall, they considered this to provide convincing evidence that improved hand hygiene through multimodal implementation strategies can reduce HCAI rates. Despite study limitations, most reports showed a temporal relation between improved hand hygiene practices and reduced infection and cross-transmission rates.

The WHO Clean Care is Safer Care team has evaluated the available evidence about the impact of hand hygiene improvement interventions to reduce transmission and/or infections by multidrug resistant organisms (MDROs) by conducting a systematic literature review from 1980 to 2013. Strong evidence from this review emphasized that hand hygiene was used as the main intervention and a significant improvement in hand hygiene compliance and/or increased alcohol-based handrub (ABHR) consumption were achieved, and such improvements were associated with substantial decreases in MDRO infections and/or colonization rates, mainly for MRSA. The effectiveness of hand hygiene by using ABHR was also emphasized in a randomized control trial to evaluate different guidance for hand hygiene (comparing the WHO’s 6-step and the CDC’s 3-step hand hygiene techniques), which provided the first evidence in clinical practice that the 6-step technique was microbiologically more effective at reducing the median \( \log^{10} \) bacterial count than the 3-step technique. Linking improved compliance to clinical outcomes such as number of infections prevented would provide more direct evidence about value of such interventions. Some gaps and key areas where more research is needed were also identified. For example, the systematic review of the effectiveness of hand hygiene interventions reported that the majority of studies came from in high-income countries and, despite limited direct evidence in hospital settings, clinical or microbiological outcomes are consistent with substantial reductions in infections for some pathogens, such as MRSA. High quality surveillance data on antimicrobial resistance (AMR) and better assessments of the impact of interventions based on hand hygiene promotion activities are urgently needed from low- to- middle income countries.
In summary, promoting hand hygiene practice among HCWs has been found to be associated with significant reductions in the number of HCAIs and MDRO infections and/or colonisation rates.

2.3.2 Hand hygiene practice among healthcare worker

As described in the previous section, hand hygiene is considered to be a key measure in preventing HCAI and the spread of antimicrobial resistance in hospital settings. However, it has also been shown that HCWs encounter difficulties in complying with hand hygiene indications at different levels.

The summary of hand hygiene behaviour from the WHO noted that insufficient or very low compliance rates have been reported from both developed and developing countries, with mean baseline rates ranging from 5% to 89% and an overall average of 38.7%. Hand hygiene performance varies according to work intensity and several other factors in hospitals.

In summary, although many countries have guidelines regarding hand hygiene for healthcare settings, overall compliance among HCWs remains poor. Most of the studies in this summary represent single sites/single wards (such as ICU, medical ward), and the majority of the data come from developed countries. More work is needed to address compliance among HCWs in developing countries. Reducing HCAIs requires that HCWs take responsibility for ensuring that hand hygiene becomes a part of routine patient care.

Hand hygiene practice among healthcare workers in Thailand

In 2003, a quasi-experimental-time series study aimed to identify the impact of a promotion programme (including a training sessions, regular performance feedback, poster displays, provision of bedside alcohol-based handrub solution, and the distribution of individual bottles of alcohol-based hand rub) on hand hygiene practices in 26 nursing personnel and its effect on nosocomial infection rates in a neonatal ICU of a university hospital. After implementing a hand hygiene promotion programme, compliance with hand hygiene among nursing personnel improved significantly from
6.3% before the programme to 81.2% after 7 months of the programme. The compliance rate did not correlate with the intensity of patient care. The nosocomial infection rate did not decrease after the intervention, possibly because of the multifactorial nature of infections (or possibly reflecting lack of statistical power).\textsuperscript{[72]}

In 2004, an observational study from 8 wards, in a 750-bed university hospital reported that the average compliance by direct observation was 24.1% (95% confidence interval [CI] = 20.5-27.9) ranging from 17.6 % to 80.0%, and the compliance rates differed between healthcare professionals and between wards.\textsuperscript{[84]}

In 2005, a cross-sectional survey aimed to determine the baseline compliance regarding hand hygiene of HCWs and visitors in ICUs at King Chulalongkorn Memorial Hospital. Overall hand-hygiene compliance obtained from this observational study was less than 50% and differed markedly among various professional categories of HCWs and visitors. The best compliance was observed in nursing students with 100% adherence, which was better than that of the nurses (71.9%) and nursing assistants (63.9%), while the adherence of the physician group was poor (14.3%).\textsuperscript{[85]}

In 2012, a quasi-experimental study aimed to evaluate behavioral-based interventions to improve hand hygiene among HCWs in 6 ICUs at a tertiary care center. Computer-generated randomization of 6 ICUs was to 1 of 3 strategies: hand hygiene education by infection control division every 3 months (S1; n = 2 units), intensified hand hygiene interventions (S2; n = 2 units), or intensified hand hygiene interventions plus increased availability of alcohol-based handrub throughout the unit (S3; n = 2 units). Intensified hand hygiene education included monthly education that emphasized hand hygiene adherence and impact on patient safety, as well as weekly workgroup discussions exploring reasons for not performing hand hygiene among HCWs with different behaviors. These discussions aimed to promote incremental commitment to the five moments for hand hygiene. Observation of hand hygiene practice amongst HCWs was based on the WHO five moments for hand hygiene recommendations. Compared with the pre-intervention period, overall post-intervention hand
hygiene adherence improved in HCWs assigned to S2 (65% vs. 85%; P=0.02) and S3 (66% vs. 95%; P=0.005) but not S1 (68% vs. 71%; P=0.84). Improvement in hand hygiene adherence was demonstrated among HCWs who reported lower stages of hand hygiene commitment in S2 (21% vs. 84%; P<0.001) and S3 (24% vs. 89%; P<0.001) and in HCWs who self-reported higher stages of commitment in S3 (78% vs. 96%; P<0.001). The study concluded that HCW hand hygiene programs may benefit from different tailored strategies to promote sustained hand hygiene adherence.\[86\]

**In summary**, a few studies that have reported hand hygiene compliance among HCWs in Thailand have been published. Data come from university and tertiary hospitals, and all of the data are not hospital wide. A wide range of hand hygiene compliance has been currently found in Thailand, ranging from 6% to 96 %, but all reporting hand hygiene compliance improving after implementing interventions, particularly with the behavioral-based interventions.

### 2.3.3 Factors influencing adherence to recommended hand hygiene practices

Factors influencing hand hygiene practices have been summarized by the WHO Guidelines on Hand Hygiene in Health Care\[78\] in Appendix A.1, which classified these factors into three groups:

i) observed risk factors,  
ii) self-reported factors, and iii) perceived barriers.

Pittet and Boyce also classified factors associated with non-compliance with hand hygiene into three levels:\[87\]

i. *individual level*; including lack of education / experience, lack of knowledge of guidelines, being a refractory non-complier  
ii. *group level*; including lack of education / lack of performance feedback on hand hygiene adherence, high workload, downsizing / understaffing, lack of encouragement / role model from key staff
iii. institutional level; lack of existing guidelines (written), lack of available / suitable hand-hygiene agents, lack of skin care promotion / agent, lack of hand hygiene facilities, lack of culture / tradition of compliance, lack of administrative leadership / sanction / rewarding/suppor

In Thailand, few studies have addressed factors associated with non-compliance. A cross-sectional survey in a questionnaire-based study aimed to assess the attitudes and beliefs regarding hand hygiene of HCWs and visitors in ICUs at King Chulalongkorn Memorial Hospital.[85] It found similar reasons for non-compliance as those outlined in the WHO report.[78] These included patient needs perceived as a priority, forgetfulness, and skin irritation by hand-hygiene agents. Subjects believed they could improve their compliance by multiple strategies including: making available hand-hygiene agents less likely to cause irritation, information of current NI rates, and easily accessed hand-hygiene supplies. The majority of the subjects claimed to know correct techniques of hand-hygiene. Handwashing with medicated soap was perceived to be the best means of hand decontamination.[85]

In summary, factors of non-compliance come from several levels of the hospital setting. It is important to address these before designing an intervention to improve hand hygiene. Psychological aspects such as attitude or beliefs regarding hand hygiene guidelines need to be considered as potentially important factors of non-compliance as well.

2.4 Behaviour change

Behaviour change is the key to improving healthcare and health outcomes[88] in particular for HCWs’ behaviour. This section aims to review behavioural considerations important for understanding and improving hand hygiene behaviour amongst HCWs. This part reviews three topics: i) behavioural considerations for hand hygiene, ii) what is a behaviour change intervention?, and iii) applying behaviour change theory to improve hand hygiene behaviour.
2.4.1 Behavioural consideration on hand hygiene

The WHO’s Guidelines on Hand Hygiene in Health Care (published in 2009) considered behavioral aspects of hand-hygiene. The report emphasized that such behavioural change dynamics are complex and multi-faceted, but are of vital importance when designing hand hygiene improvement strategies. A theory-based model to explain human behaviour was presented. This classified relevant factors on the basis of being directed at the individual (intrapersonal), interpersonal, or community levels. Intrapersonal factors are individual characteristics, such as knowledge, attitudes, beliefs and personality traits, that influence behaviour. Interpersonal factors include groups who provide social identity, support and role definition. These include family, friends and peers. Community factors are social norms and networks that exist between individuals, groups and organizations. In a hospital setting, the relevant community level would often be the ward.

Whitby et al. applied social psychology in an attempt to understand and explain behavioural patterns of hand hygiene behaviour. This behaviour has been shown to vary substantially among HCWs within the same hospital or ward, indicating that both individual and community influences play a role in determining this behaviour.

In summary, the WHO classified factors affecting hand hygiene behavior into three levels: intrapersonal, interpersonal, and community factors. A similar classification was used by Michie et al. These different levels of factors affecting hand hygiene need to be systematically addressed for individual settings when designing interventions.

2.4.2 What is a behaviour change intervention?

‘Behaviour change interventions’ can be defined as "coordinated sets of activities designed to change specified behaviour patterns". Improving the implementation of evidence-based practice requires effective behaviour change interventions. An appropriate method for characterising interventions and
linking them to an analysis of the targeted behaviour can help the process of designing effective interventions.\cite{37}

**The Behaviour Change Wheel’s COM-B system**

The Behaviour Change Wheel (BCW) approach\cite{91} is underpinned by a causal analysis of behaviour. It starts with the question: ‘What conditions internal to individuals and in their social and physical environment need to be in place for a specified behavioural target to be achieved?’ The ‘intervention mapping’ approach, in contrast, starts with the question: ‘What factors in the present population at the present time underlie variation in the behavioural parameter?’ The BCW approach draws from a single theory of motivation in context that predicts what aspects of the motivational system need to be influenced and in what ways do they need to be influenced to achieve a specified behavioural change. In contrast the ‘intervention mapping’ approach is based on a number of different theoretical approaches each of which addresses different aspects of the behaviour.\cite{91}

Michie et al. summarized a new method for characterizing and designing behaviour change interventions is called the 'COM-B' system.\cite{37} This system is considered as a 'behaviour system', where system components interact to generate behaviour. Capability is defined as "the individual’s psychological and physical capacity to engage in the activity concerned"; having the necessary knowledge and skills is one component of capability. Motivation can be defined as "all those brain processes that energize and direct behaviour, not just goals and conscious decision-making". Motivation includes "habitual processes, emotional responding, as well as analytical decision-making". Opportunity is defined as "all the factors that lie outside the individual that make the behaviour possible or prompt it".\cite{37} (Table 2.3)
Table 2.2: Mapping of the Behaviour Change Wheel’s COM-B system to the TDF Domains, from Cane et al., 2012.\cite{88}

<table>
<thead>
<tr>
<th>COM-B component</th>
<th>TDF Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capability</td>
<td>Psychological Knowledge</td>
</tr>
<tr>
<td></td>
<td>Skills</td>
</tr>
<tr>
<td></td>
<td>Memory, Attention and Decision</td>
</tr>
<tr>
<td></td>
<td>Behavioural Regulation</td>
</tr>
<tr>
<td>Physical</td>
<td>Skills</td>
</tr>
<tr>
<td>Opportunity</td>
<td>Social</td>
</tr>
<tr>
<td></td>
<td>Social Influences</td>
</tr>
<tr>
<td>Physical</td>
<td>Environmental Context and</td>
</tr>
<tr>
<td>Motivation</td>
<td>Reflective</td>
</tr>
<tr>
<td></td>
<td>Social/Professional Role &amp;</td>
</tr>
<tr>
<td></td>
<td>Beliefs about Capabilities</td>
</tr>
<tr>
<td></td>
<td>Optimism</td>
</tr>
<tr>
<td></td>
<td>Beliefs about Consequences</td>
</tr>
<tr>
<td></td>
<td>Intentions</td>
</tr>
<tr>
<td></td>
<td>Goals</td>
</tr>
<tr>
<td>Automatic</td>
<td>Social/Professional Role &amp;</td>
</tr>
<tr>
<td></td>
<td>Optimism</td>
</tr>
<tr>
<td></td>
<td>Reinforcement</td>
</tr>
<tr>
<td></td>
<td>Emotion</td>
</tr>
</tbody>
</table>

The theoretical domain frameworks

The Theoretical Domains Framework (TDF) is an "integrative framework of theories of behaviour change".\cite[92]{92} This framework aims to "simplify and integrate a plethora of behaviour change theories and make theory more accessible to, and usable by, other disciplines".\cite{88} The TDF consists of fourteen domains which cover different aspects of behaviour. (Table 2.4)
<table>
<thead>
<tr>
<th>Theoretical Domain</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>An awareness of the existence of something</td>
</tr>
<tr>
<td>Skills</td>
<td>An ability or proficiency acquired through practice</td>
</tr>
<tr>
<td>Social/Professional Role and Identity</td>
<td>A coherent set of behaviors and displayed personal qualities of an individual in a social or work setting</td>
</tr>
<tr>
<td>Beliefs about capabilities</td>
<td>Acceptance of truth, reality or validity about an ability, talent or facility that person can put to constructive use</td>
</tr>
<tr>
<td>Optimism</td>
<td>The confidence that things will happen for the best or that desired goals will be attained</td>
</tr>
<tr>
<td>Beliefs about consequence</td>
<td>Acceptance of truth, reality or validity about outcomes of behavior in a given situation</td>
</tr>
<tr>
<td>Reinforcement</td>
<td>Increasing of probability of response by arranging a dependent relationship, or contingency, between the response and a given stimulus</td>
</tr>
<tr>
<td>Intentions</td>
<td>A conscious decision to perform a behavior or a resolve to act in a certain way</td>
</tr>
<tr>
<td>Goals</td>
<td>Mental representations of outcomes or end states that an individual wants to achieve</td>
</tr>
<tr>
<td>Memory, attention and decision processes</td>
<td>The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives</td>
</tr>
<tr>
<td>Environmental context and resource</td>
<td>Any circumstance of a person’s situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behavior</td>
</tr>
<tr>
<td>Social influences</td>
<td>Those interpersonal processes that can cause individuals to change their thoughts, feelings or behaviors</td>
</tr>
</tbody>
</table>
Table 2.3: Domains in the theoretical domains framework, from Cane et al., 2012.\cite{88} (cont.)

<table>
<thead>
<tr>
<th>Theoretical Domain</th>
<th>Definition\cite{88}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emotion</td>
<td>A complex reaction pattern, involving experiential, behavioral and physiological elements, by which the individual attempts to deal with a personally significant matter or event</td>
</tr>
<tr>
<td>Behavioral regulation</td>
<td>Anything aimed at managing or changing objectively observed or measured actions</td>
</tr>
</tbody>
</table>

This framework has been used to explain implementation problems and inform implementation intervention in many healthcare systems, including applications to hand hygiene.\cite{35, 93} Most of this research has used interviews and focus groups to provide details of factors related to behaviour change.

In recent years, there has been a lot of interest in using the TDF for changing clinical practice, as it represents a unifying theoretical framework to identify systematically the key aspects behavioural change including intrapersonal (individual), interpersonal, institutional and community factors.\cite{42} (Table 2.5)

Use of the COM-B may help identify those TDF domains\cite{42} which are likely to be important in changing behaviour (Table 2.3). The advantage of this type of behavioural analysis is that "intervention designers can be selective about the domains they investigate to inform the nature of the intervention".\cite{42}
Table 2.4: Constructs in four theoretical domains, illustrating individual, team, and organizational levels based on construct allocations, from Michie et al., 2005.\(^{[42]}\)

<table>
<thead>
<tr>
<th>Domain</th>
<th>Individual</th>
<th>Team</th>
<th>Organizational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Context and Resources</td>
<td>Environmental stressors</td>
<td>Environmental stressors</td>
<td>Resources/material</td>
</tr>
<tr>
<td>Resources</td>
<td>Person × environment interaction</td>
<td></td>
<td>(availability and management)</td>
</tr>
<tr>
<td>Social Influences</td>
<td>Social support</td>
<td>Leadership</td>
<td>Organizational</td>
</tr>
<tr>
<td></td>
<td>Social pressure</td>
<td>Social comparisons</td>
<td>climate/culture</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Change management</td>
</tr>
<tr>
<td>Social/Professional Role and Identity</td>
<td>Identity</td>
<td>Professional identity</td>
<td>Organizational</td>
</tr>
<tr>
<td></td>
<td></td>
<td>boundaries/role</td>
<td>commitment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group/social identity</td>
<td></td>
</tr>
<tr>
<td>Behavioural Regulation</td>
<td>Goal/target setting</td>
<td>Goal/target setting</td>
<td>Goal/target setting</td>
</tr>
<tr>
<td></td>
<td>Self-monitoring</td>
<td>Self-monitoring</td>
<td>Barriers and facilitators</td>
</tr>
</tbody>
</table>

2.4.3 Applying behaviour change theory to improve hand hygiene behaviour

In recently published research, behaviour change theory has been formally applied to address two key aspects of hand hygiene behaviour: firstly, in addressing key determinants of hand hygiene when designing the initial intervention, and secondly in the phase of implementing the intention.

Designing the intervention

Suggestions for the steps needed to develop the behaviour change intervention by using the TDF were reviewed by Frech et al.\(^{[94]}\). This produced a four-step approach to guide the choice of the most appropriate components of an implementation intervention (Table 2.6).
The Medical Research Council guidance in developing and evaluating complex intervention also described key elements in the development and evaluation process, which considered identifying or developing theory as key step.[95]

For hand hygiene behaviour, factors that influence hand hygiene compliance among HCWs have been addressed in several studies using qualitative methods.[96-99]

Important advantages (protection of patient and self), disadvantages (time, hand damage), referents (supportive: patients, colleagues; unsupportive: some doctors), barriers (being too busy, emergency situations), and facilitators (accessibility of sinks/products, training, reminders) were identified among Australian hospital-based nurses.[96] It was argued that interventions to improve nurses’ hand hygiene practice across the five moments needed to “focus on individual strategies to combat distraction from other duties, peer-based initiatives to foster a sense of shared responsibility, and management-driven solutions to tackle staffing and resource issues”.[96]

A number of key determinants that physicians believe influence whether or not and when they practice hand hygiene have been addressed. This has helped to identify potential individual, team, and organization targets for behavior change interventions.[98] Semi-structured interviews based on the 14 TDFs of a behaviour change framework have been employed to explain health-related behaviour change that influences physician hand hygiene compliance. This study identified nine relevant domains influencing hand hygiene behaviour including “knowledge”; “skills”; “beliefs about capabilities”; “beliefs about consequences”; “goals”; “memory, attention, and decision processes”; “environmental context and resources”; “social professional role and identity”; and “social influences”.[98]

Consideration of HCWs’ “real-time” explanations for noncompliance identified “Memory/Attention/Decision Making” and “Knowledge” as two key behavioral domains commonly linked to noncompliance. This suggests that hand hygiene interventions should target both “conscious decision
making and automatic processes (working on “auto-pilot”) by, for example, using “If-Then” plans and ensuring good knowledge.” Fuller et al. argued that a TDF to investigate HCW’s “real-time” explanations of noncompliance provides a "coherent" way to design hand hygiene interventions.[99]

In summary, understanding existing causes of poor hand hygiene compliance and which barriers and enablers need to be addressed is an important requirement for designing hand hygiene promotion interventions having a good chance of success.

Implementing the intervention

Huis et al. published a systematic review of hand hygiene improvement strategies and applied a behavioural approach in their analysis.[100] This led to a taxonomy of behavioural change techniques which was used to identify targeted determinants. Determinants of behaviour change are the determinants targeted by a systematically developed strategy i.e. things that have been identified for altering behaviours. Theoretically, the application of a chosen behaviour change activity as part of the hand hygiene improvement strategy will alter a specific behavioural determinant, which in turn will change behaviours. An example application of behaviour change techniques for improving hand hygiene from this study is presented in Table 2.7.
Table 2.5: Steps for developing a theory-informed implementing intervention, from French et al., 2012[94]

<table>
<thead>
<tr>
<th>Step</th>
<th>Tasks</th>
</tr>
</thead>
</table>
| STEP 1: Who needs to do what, differently? | • Identify the evidence-practice gap  
• Specify the behaviour change needed to reduce the evidence-practice gap  
• Specify the health professional group whose behaviour needs changing |
| STEP 2: Using a theoretical framework, which barriers and enablers need to be addressed? | • From the literature, and experience of the development team, select which theory (ies), or theoretical framework(s), are likely to inform the pathways of change  
• Use the chosen theory(ies), or framework, to identify the pathway(s) of change and the possible barriers and enablers to that pathway  
• Use qualitative and/or quantitative methods to identify barriers and enablers to behaviour change |
| STEP 3: Which intervention components (behaviour change techniques and mode(s) of delivery) could overcome the modifiable barriers and enhance the enablers? | • Use the chosen theory, or framework, to identify potential behaviour change techniques to overcome the barriers and enhance the enablers  
• Identify evidence to inform the selection of potential behaviour change techniques and modes of delivery  
• Identify what is likely to be feasible, locally relevant, and acceptable and combine identified components into an acceptable intervention that can be delivered |
| STEP 4: How can behaviour change be measured and understood? | • Identify mediators of change to investigate the proposed pathways of change  
• Select appropriate outcome measures  
• Determine feasibility of outcomes to be measured |
Forty-one studies of experimental and quasi-experimental research on hand hygiene improvement strategies were reviewed in this study. The most frequently addressed determinants were knowledge, awareness, action control, and facilitation of behaviour. Relatively few studies addressed social influence, self-efficacy, attitude, and intention. There were thirteen studies using controlled designs to assess the effects of improvement strategies on hand hygiene behaviour. The reported effectiveness of the strategies varied substantially, but most controlled studies showed positive results as assessed by relative difference in hand hygiene compliance. Relative difference is defined here as the compliance in the intervention group minus the compliance from the control group) divided by the compliance from the control group after the intervention. The median effect for these strategies was a relative difference (improvement) of 17.6% in hand hygiene compliance. The effect size from one controlled study addressing two determinants was a relative difference of 25.7%. The relative difference increased from 42.3% in the three studies addressing three determinants to 43.9% for the two studies addressing four determinants. The relative difference was 49.5% for the three studies that addressed five determinants. By focusing on determinants of behaviour change, the authors argued, it is possible to find valuable and otherwise hidden components in hand hygiene improvement strategies. The authors also argued that addressing only determinants such as knowledge, awareness, action control, and facilitation is not enough to change hand hygiene behaviour. Addressing combinations of different determinants showed better results. This indicated a need for more creativity in the application of alternative improvement activities addressing determinants such as social influence, attitude, self-efficacy, or intention.

In a study by McAteer et al., semi-structured interviews to identify the barriers to and facilitators of implementation were performed with 17 ward coordinators who had delivered a feedback intervention to improve hand hygiene.[101] The lower scoring domains and those indicating low likelihood of successful implementation of trial interventions were “environmental context and resources”, “beliefs about capabilities”, “social influences”, and “emotion”. The lowest scoring domain
was “environmental context and resources”. Lack of time, understaffing, perceived negativity from co-workers, and stress were identified as challenges. Ward coordinators described difficulties finding time to implement the trial within the context of existing routines and increased clinical workload because of staffing issues. In these instances, implementing the trial became a low priority. Ward coordinators stated that, whereas they felt equipped to deliver the intervention, they had concerns about their capabilities to do so within the context of available time and staffing. The higher scoring domains and those indicating greater likelihood of successful implementation of the trial were “behavioral regulation,” “motivation,” “skills,” “knowledge,” and “professional role”. Ward coordinators reported that they believed they had the relevant skills, understanding, and motivation to implement the intervention.[101]

In summary, behaviour change theory and techniques can help find new pathways for increasing hand hygiene and can also be valuable for classifying and understanding previously described approaches.
**Table 2.6:** Example of application of behaviour change techniques for improving hand hygiene behaviour by determinants from a systematic review of studies of the promotion of hand hygiene in HCWs, from Huis *et al.*, 2012

<table>
<thead>
<tr>
<th>Determinants</th>
<th>Behaviour change technique</th>
<th>Description of the activity in studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>Provide general information</td>
<td>Educational sessions or educational materials</td>
</tr>
<tr>
<td></td>
<td>Increase memory or understanding of information</td>
<td>Group discussion, answering questions, clarification</td>
</tr>
<tr>
<td>Awareness</td>
<td>Risk communication</td>
<td>Information about risks of non-adherence or inadequate hand hygiene (infection rates, costs)</td>
</tr>
<tr>
<td></td>
<td>Delayed feedback of behaviour</td>
<td>Overview of recorded hand hygiene behaviour</td>
</tr>
<tr>
<td></td>
<td>Direct feedback of behaviour</td>
<td>Using a system to make professionals aware of their hand hygiene behaviour soon after planned execution</td>
</tr>
<tr>
<td>Social influence</td>
<td>Provide information about peer behaviour</td>
<td>Information about peers’ opinions of correct hand hygiene</td>
</tr>
<tr>
<td></td>
<td>Provide opportunities for social comparison</td>
<td>Group sessions with peers in which discussion and social comparison of hand hygiene practices can occur</td>
</tr>
<tr>
<td></td>
<td>Mobilise social norm</td>
<td>Exposing the professional to the social norm of important others (not peers) such as opinion leaders</td>
</tr>
<tr>
<td>Attitude</td>
<td>Persuasive communication</td>
<td>Positive consequences of proper hand hygiene</td>
</tr>
<tr>
<td></td>
<td>Reinforcement of behavioural progress</td>
<td>Praise, encouragement, or material rewards</td>
</tr>
</tbody>
</table>
### Table 2.6: Example of application of behaviour change techniques for improving hand hygiene behaviour by determinants from a systematic review of studies of the promotion of hand hygiene in HCWs, from Huis et al., 2012\(^{[100]}\) (cont.)

<table>
<thead>
<tr>
<th>Determinants</th>
<th>Behaviour change technique</th>
<th>Description of the activity in studies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-efficacy</strong></td>
<td>Modeling</td>
<td>Use of a role model. Demonstration of proper hand hygiene behaviour in group, class, or team</td>
</tr>
<tr>
<td></td>
<td>Verbal persuasion</td>
<td>Messages designed to strengthen control beliefs about the way of performing correct hand hygiene</td>
</tr>
<tr>
<td></td>
<td>Guided practice</td>
<td>Teaching skills and providing feedback. Specific instruction for correct hand hygiene behaviour</td>
</tr>
<tr>
<td></td>
<td>Plan coping responses</td>
<td>Identification and coping with potential barriers</td>
</tr>
<tr>
<td></td>
<td>Set graded tasks, goal setting</td>
<td>Desired hand hygiene behaviour is achieved with a stepwise model</td>
</tr>
<tr>
<td><strong>Intention</strong></td>
<td>General intention information</td>
<td>Explanation of the goals and targets concerning hand hygiene</td>
</tr>
<tr>
<td></td>
<td>Agree to behavioural contract</td>
<td>Contract or commitment with formulated goals of hand hygiene behaviour</td>
</tr>
<tr>
<td><strong>Action control</strong></td>
<td>Use of cues</td>
<td>Reminders</td>
</tr>
<tr>
<td><strong>Facilitation of behaviour</strong></td>
<td>Provide materials to facilitate behaviour</td>
<td>Supportive materials are provided for the healthcare workers</td>
</tr>
<tr>
<td></td>
<td>Continuous professional support</td>
<td>Involves service provided by infection control team or working group, and/or an additional nurse who attends the implementation</td>
</tr>
</tbody>
</table>
2.5  Interventions to improve hand hygiene with recommendations of the World Health Organization

2.5.1  The multimodal strategy

The WHO report on implementing their multimodal improvement strategy argued equal importance should be attached to each component and that each component requires efforts to achieve effective implementation and maintenance, though hospitals around the world may have progressed to different levels in each of these strategies. A multimodal strategy has been found to be an effective way to improve compliance in HCWs, based on an analysis of evidence from higher quality studies in a recent systematic review and network meta-analysis.

The components of the multimodal strategy, as described by the WHO in their guide to implementation, are:

1. **System change**: ensuring that the necessary infrastructure is in place to allow health-care workers to practice hand hygiene. This includes two essential elements:
   - access to a safe, continuous water supply as well as to soap and towels;
   - readily accessible alcohol-based handrub at the point of care.

2. **Training / Education**: providing regular training on the importance of hand hygiene, based on the “My 5 Moments for Hand Hygiene” approach, and the correct procedures for handrubbing and handwashing, to all health-care workers.

3. **Evaluation and feedback**: monitoring hand hygiene practices and infrastructure, along with related perceptions and knowledge among health-care workers, while providing performance and results feedback to staff.
4. **Reminders in the workplace:** prompting and reminding health-care workers about the importance of hand hygiene and about the appropriate indications and procedures for performing it.

5. **Institutional safety climate:** creating an environment and the perceptions that facilitate awareness-raising about patient safety issues while guaranteeing consideration of hand hygiene improvement as a high priority at all levels, including
   - active participation at both the institutional and individual levels;
   - awareness of individual and institutional capacity to change and improve (self-efficacy); and
   - partnership with patients and patient organizations

### 2.5.2 My five moments

Within the framework of the WHO’s First Global Patient Safety Challenge known as “Clean Care is Safer Care,” an evidence-based, user-centered concept, “My five moments for hand hygiene,” (Table 2.8) was developed for measuring, teaching, and reporting hand hygiene behaviour. This concept is an essential part of the WHO’s hand hygiene improvement strategy which aims to translate the WHO Guidelines on Hand Hygiene in Health Care into practice.
<table>
<thead>
<tr>
<th>Indication term for hand hygiene</th>
<th>Departure hand-to surface exposure</th>
<th>Hand transition and microorganism transmission risk</th>
<th>Arrival hand-to-surface exposure</th>
<th>Major targeted negative infectious outcome</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before touching a patient</td>
<td>Surface outside the patient zone</td>
<td>Hand transmission of microorganisms from the health care environment to the patient</td>
<td>Patient’s intact skin and other surfaces inside the patient zone</td>
<td>Colonization of the patient by hospital pathogens</td>
<td>Touching the door handle and then shaking hands with the patient</td>
</tr>
<tr>
<td>Before aseptic/clean procedure</td>
<td>Any surface</td>
<td>Hand transmission of microorganisms from any surface (including the patient skin) to a site that would facilitate invasion and infection</td>
<td>Critical site for infection in the patient</td>
<td>Endogenous or exogenous infection of the patient</td>
<td>Preparing the material and then giving an injection</td>
</tr>
<tr>
<td>After body fluid exposure risk</td>
<td>Critical site for body fluid exposure in HCWs</td>
<td>Hand exposure to patient’s body fluids potentially containing blood-borne or other pathogens</td>
<td>Any surface</td>
<td>Infection of the HCW by patient bloodborne pathogens</td>
<td>Drawing blood and then adjusting the infusion drop count</td>
</tr>
</tbody>
</table>
### Table 2.7: The “My five moments for hand hygiene” concept and transmission risks, from Sax et al., 2009[102] (cont.)

<table>
<thead>
<tr>
<th>Indication term for hand hygiene</th>
<th>Departure hand-to-surface exposure</th>
<th>Hand transition and microorganism transmission</th>
<th>Arrival hand-to-surface exposure</th>
<th>Major targeted negative infectious outcome</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>After touching a patient</td>
<td>Patient’s intact skin and other surfaces inside the patient zone</td>
<td>Hand transmission of microorganisms from the patient flora to other surfaces in the health care setting</td>
<td>Surface outside the patient zone</td>
<td>Dissemination of patient flora to the rest of the health care environment and infection of HCWs</td>
<td>Shaking hands with the patient, arranging the bedside table, and then touching the door handle</td>
</tr>
<tr>
<td>After touching patient surroundings (without touching the patient during the same care sequence)</td>
<td>Surface inside the patient zone if the patient was not touched</td>
<td>Hand transmission of microorganisms from the patient flora to other surfaces in the health care setting</td>
<td>Surface outside the patient zone</td>
<td>Dissemination of patient flora to the rest of the health care environment and then touching the door handle</td>
<td>Touching the bed rail (without touching the patient) and then touching the door handle</td>
</tr>
</tbody>
</table>
2.5.3 Applying the WHO strategy in healthcare settings

A systematic review of methodologically strong studies to assess the relative effectiveness of the WHO Five Multimodal Hand Hygiene Improvement Strategy (WHO-5) and other strategies for improving compliance with hand hygiene in healthcare workers in hospital settings during 1980 to 2014 was recently published by Luangasanatip et al.\[82\] This review also aimed to summarize associated information on use of resources.

Forty-one studies met the inclusion criteria, including 6 randomised controlled trials, 32 interrupted time series studies, one non-randomized trial, and two controlled before-after studies.

Key findings from this review are:

i. Network meta-analyses of included studies provided evidence that the WHO campaign is effective at increasing compliance with hand hygiene in healthcare workers.

ii. There was evidence that additional interventions (used in conjunction with the WHO campaign elements), including goal setting, reward incentives, and accountability, can lead to further improvements.

iii. Reporting on resource implications of such interventions is limited.

Nineteen studies reported clinical outcomes. These outcome data were consistent with clinically important reductions in rates of infection resulting from improved hand hygiene for some but not all important hospital pathogens.

Network meta-analysis indicated considerable uncertainty in the relative effectiveness of interventions, but nonetheless provided evidence that WHO-5 is effective and that compliance can be further improved by adding interventions including goal setting, reward incentives, and accountability (Figure 2.2).
Table 2.8: Description of hand hygiene intervention by components, from Luangasanatip et al., 2015. [82]

<table>
<thead>
<tr>
<th>Type of Hand hygiene intervention component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. System change *</td>
<td>Ensuring necessary infrastructure is available including a) access to water, soap and towels and b) alcohol-based handrub at the point of care.</td>
</tr>
<tr>
<td>2. Education and Training</td>
<td>Providing training or educational programme on the importance of hand hygiene and the correct procedures for hand hygiene, for healthcare workers.</td>
</tr>
<tr>
<td>3. Feedback</td>
<td>Monitoring hand hygiene practices among healthcare workers while providing the compliance feedback to staff.</td>
</tr>
<tr>
<td>4. Reminders at workplace</td>
<td>Prompting healthcare workers either through printed material, verbal reminders, electronic communications or other methods, to remind them about the importance of hand hygiene and the appropriate indications and procedures.</td>
</tr>
<tr>
<td>5. Institutional safety climate</td>
<td>Active participation at institutional level, creating an environment allowing prioritization of hand hygiene.</td>
</tr>
<tr>
<td>6. Goal-setting</td>
<td>Setting of specific goals aimed at improving hand hygiene compliance, which may both apply at the individual and group level and may include healthcare associated infection rates.</td>
</tr>
<tr>
<td>7. Reward incentives</td>
<td>Interventions involved with providing any reward incentive for the participants once they achieve a particular task or reach a certain level of hand hygiene compliance. Both non-financial and financial rewards are included.</td>
</tr>
<tr>
<td>8. Accountability</td>
<td>Interventions involved with improving healthcare workers’ accountability both at an individual and unit level.</td>
</tr>
</tbody>
</table>

* If the intervention period included changing the place or formulation or installing more dispensers of alcohol based handrub, the baseline intervention was counted as no intervention or standard practice (no system change component) although the alcohol-based handrub had been used during the baseline.
This systematic review also highlighted methodological weaknesses in many hand hygiene studies and noted that few studies meeting minimal quality criteria came from developing countries. A similar finding came from the systematic review of Gould et al. in 2010, though only four studies met the inclusion criteria in this review.\textsuperscript{[103]}

**In summary**, there is good evidence that the WHO-5 intervention is effective at promoting hand hygiene. Stronger study designs including randomized controlled trials and interrupted time series analyses should be more frequently used in the evaluation of interventions to promote hand hygiene.

**Figure 2.2**: Box-and-whiskers plot showing relative efficacy of different hand hygiene intervention strategies compared with standard of care estimated by network meta-analysis from interrupted time series studies. Lower and upper edges represent 25\textsuperscript{th} and 75\textsuperscript{th} percentiles from the posterior distribution; the central line represents the median. Whiskers extend to the 5\textsuperscript{th} and 95\textsuperscript{th} percentiles. Intervention strategies were single intervention; WHO-5; and WHO-5+ (WHO-5 with incentives, goal-setting, or accountability), from Luangasanatip et al., 2015.\textsuperscript{[82]}
### 2.6 The stepped wedge cluster randomized trial

This section is concerned with the study design to be used to evaluate the hand hygiene intervention as described in Chapter 5. It considers: i) what is the stepped wedge cluster randomized trial?, ii) study rationale, and iii) the stepped wedge cluster randomized trial use in health behaviour interventions.

#### 2.6.1 What is the stepped wedge cluster randomized trial?

The randomized controlled trial (RCT) is generally considered the ‘gold standard’ for evaluating the effectiveness of an intervention. But the standard RCT will not be appropriate or practical for some interventions, for example health education programmes where the intervention is applied to a group of participants. Stepped wedge cluster randomized controlled trials (SW-RCTs) may be more appropriate in such cases. A stepped wedge design is a type of cluster randomized controlled trial which is appropriate when there are prior reasons to believe the intervention will be beneficial (as opposed to equipoise) and when it is impractical to deliver the intervention to all study units simultaneously.\(^1\) The SW-RCT is increasingly being used to evaluate "service delivery" type interventions.\(^2\)

#### 2.6.2 Study rationale

This SW-RCT design is useful when i) there is prior belief that the intervention will do more good than harm, ii) there are logistical, practical or financial constraints to applying the intervention simultaneously to multiple groups, and iii) there is a need to evaluate a public policy intervention that is being rolled-out prior to effectiveness being established.\(^3\)

In a stepped wedge design, an intervention is rolled-out sequentially to the trial participants (sometimes individuals, but more typically clusters of individuals) over a number of time periods. The order in which these clusters get the intervention is determined at random according a specified
schedule. By the end of the random allocation the intervention will have been delivered to all individuals or groups. Stepped wedge designs incorporate data collection at each time point for each group, both before and after the intervention are delivered.

An example of the logistics of a stepped wedge trial design is shown in Figure 2.3, which shows a stepped wedge design with five steps. Data analysis to determine the overall effectiveness of the intervention subsequently involves comparison of the data points in the control section of the wedge with those in the intervention section.\cite{106}

**Figure 2.3:** Example of a stepped wedge design, from Brown and Lilford, 2006\cite{106}
2.6.3 The stepped wedge cluster randomized trial in health behaviour research

The SW-RCT design is increasingly used to assess health behaviour interventions in many studies involving health behaviour (including hand hygiene behaviour), as highlighted in two systematic reviews.\(^{106, 107}\)

To take one example, the Feedback Intervention Trial (FIT) was a 3-year SW-RCT of 36 months duration aimed at improving hand-hygiene compliance in UK healthcare workers.\(^{108}\) The study compared routine practice with a feedback intervention developed within a behavioural theoretical framework. The intervention was rolled out sequentially in 16 English/Welsh Hospitals (clustering within clustering) switching from control to intervention every 2 months at 5 different time points after an initial baseline period. All study wards within the hospital were allocated to start the intervention concurrently. The primary outcome was hand hygiene compliance. The study found significant sustained improvements in hand hygiene compliance in wards implementing the intervention. However, not all wards implemented the intervention according to protocol and the difficulties in implementation, and lacks of fidelity to intervention were found to be important issues in this study.

**In summary**, the SW-RCT is a good study design for evaluating the effectiveness of hand hygiene interventions, because all HCWs should receive this intervention.

Summary

Improving hand hygiene compliance amongst HCWs is one of the simplest and most effective measures for preventing HCAIs. However, only a few studies have evaluated the effectiveness of interventions for improving hand hygiene compliance using strong study designs, and almost all of these have been in high income countries. The development and evaluation of intervention to reduce HCAI in resourced-limited hospital settings is needed.
Chapter 3

Burden of hospital-acquired and healthcare-associated infections in a resource-limited hospital setting

3.1 Introduction

Nosocomial infection is a major cause of morbidity and mortality in those who receive medical care or treatment in a hospital or hospital-like setting, and surveillance must be regularly performed in a systematic way in order to reduce the rates of the infection.\textsuperscript{[109]} However there is a paucity of information about their epidemiology from developing countries despite the fact that such countries are believed to have the highest burden of nosocomial infection and account for most of the world’s population.\textsuperscript{[3]} This is particularly true for nosocomial bacteraemias which are frequently used as indicators of trends in overall nosocomial infection in developed countries because of the availability of clear definitions and clinical relevance.\textsuperscript{[109, 110]}

A recent comprehensive systematic review found only 13 studies of healthcare-associated bloodstream infection from developing countries between 1995 and 2008, with only six studies in the Southeast Asia region and none from the Western Pacific region.\textsuperscript{[3]} For example, the reported incidence rates of hospital-acquired bacteraemia (HAB) through active surveillance were 1.0 per 1,000 patient-days in a district hospital in Kenya between 2002 and 2009\textsuperscript{[111]}, and 1.2 per 1,000 patient-days in a university hospital in Iran in 2006.\textsuperscript{[112]} This lack of information is a consequence, at least in part, of the paucity of reliable surveillance systems for such outcomes in resource-limited settings.
Moreover, published literature from developing countries is often from better resourced or university hospitals \cite{111,112} and may not provide a reliable basis for generalization to public hospitals in those countries.

In this study, multiple sources of routine surveillance data are combined including microbiology databases, hospital admission databases and the national death registry from a sample of provincial hospitals in northeast Thailand.\cite{113} The objectives were to demonstrate trends in incidence, antibiotic-resistance and mortality associated with HAB and healthcare-associated bacteraemia (HCAB) over a seven year period.

### 3.2 Materials and Methods

#### 3.2.1 Study population

Northeast Thailand consists of 20 provinces, covers 170,226 km\(^2\) and had an estimated population in 2010 of 21.4 million. Each province has a provincial hospital that provides care to people living within its catchment area and acts as a referral hospital for smaller district hospitals. The number of beds per provincial hospital ranges from 200 to 1000, and all provincial hospitals are equipped with intensive care units (ICUs). Severely ill patients presenting to district hospitals are often referred to provincial hospitals. Provincial hospitals are equipped with a microbiology laboratory that provides a bacterial culture service, while district hospitals normally do not have such facilities. All microbiology laboratories in provincial hospitals use standard methodologies for bacterial identification and susceptibility testing provided by the Bureau of Laboratory Quality and Standards, Ministry of Public Health, Thailand.\cite{114}
3.2.2 Study design

A retrospective study was conducted, using surveillance data from all provincial hospitals in northeast Thailand. The data were collected as previously described. In brief, the director of each hospital was contacted and given information on the study. For those hospitals that agreed to participate, data were collected from the microbiology and hospital databases between Jan 2004 to Dec 2010. Admission number (AN) was used as the record linkage between the two databases, and hospital number (HN) was used to identify individuals who had repeated admissions. The death registry for northeast Thailand between Jan 2004 to Jan 2011 was obtained from the Ministry of Interior, Thailand, and used to identify patients who were discharged from hospital and died within 30 days after discharge from the hospital.

3.2.3 Ethical review and study permissions

Ethical permission for this study was obtained from the Ethical and Scientific Review Committees of the Ministry of Public Health, Thailand, and of Faculty of Tropical Medicine, Mahidol University (Appendix B.1). Written consent was given by the director of the hospitals to use the routine hospital database for research. Consent was not sought from the patients as this was a retrospective study, and the Ethical and Scientific Review Committees approved the process.

3.2.4 Data collection

The microbiology laboratory data collected were HN, AN, specimen type, specimen date, culture result, and antibiotic susceptibility profile (antibiogram). Hospital data were collected from the routine in-patient discharge report (Report 501), which is regularly completed by attending physicians and reported to the Ministry of Public Health, Thailand, as part of national morbidity and mortality reporting system. The data collected were HN, AN, national identification 13-digit number, gender,
age, admission date, discharge date, and outcome. A single outcome variable is required by this reporting system, which is completed by the attending physicians and categorized as cured, improved, not improved, transfer to another hospital, refusal of treatment, or died. Date of death was also extracted from this record. Data collected from the death registry obtained from the Ministry of Interior were national identification 13-digit number and date of death. Data are not suitable for public deposition due to ethical restrictions. Raw database requests may be made to the director of each participating hospital (Appendix B.2).

3.2.5 Definitions

Bacteraemia was classified as community-acquired bacteraemia (CAB), HAB or HCAB. CAB was defined as the isolation of a pathogenic organism from blood taken in the first 2 days of admission and without a hospital stay in the 30 days prior to admission. HAB was defined as the isolation of a pathogenic organism from blood taken after the first 2 days of admission. HCAB was defined as the isolation of a pathogenic organism from blood taken in the first 2 days of admission and with a hospital stay within 30 days prior to the admission. Patients at risk of HCAB were those with a hospital stay within 30 days prior to the admission. Patients were considered at risk of HAB after they stayed in the hospital for more than 2 days.

Because of the difficulty in establishing their clinical significance, organisms frequently associated with contamination including coagulase-negative *Staphylococci*, Viridans group *Streptococci*, *Corynebacterium* spp., *Bacillus* spp., *Diptheroid* spp., *Micrococcus* spp., and *Propionibacterium* spp. were excluded from the analysis. Organisms that produced an extended-spectrum β lactamase (ESBL) were defined using standard methodologies for bacterial identification and susceptibility testing provided by the Bureau of Laboratory Quality and Standards, Ministry of Public Health, Thailand. All patients with bacteraemia caused by *B. pseudomallei* were categorized as CAB because this organism is not a cause of HAB or HCAB. Polymicrobial infection was defined in
patients who had more than one species of pathogenic organisms isolated from the blood during the same episode. Information on patients with a first CAB episode has been published previously.\textsuperscript{[110]} In this study, patients with a first episode of HAB or HCAB were evaluated in relation to epidemiology and mortality.

The 30-day mortality of HAB was determined on the basis of a record of death within 30 days of the positive blood culture taken as recorded in the routine hospital database or by a record of death in the national death registry. The 30-day mortality of HCAB was defined as death within 30 days of the admission date. The incidence rate of HAB was calculated as the number of HAB per 1,000 patient-days at risk. The cumulative incidence of HCAB was calculated as the number of HCAB per 100 readmissions. To avoid the assessment of multiple outcomes for a single patient, in the event that a patient had more than one episode of bacteraemia (either HAB and/or HCAB) only the first episode was included in the study.

3.2.6 Statistical analysis

All analyses were performed using STATA version 12.0 (StataCorp LP, College station, Texas). Poisson regression models were used to calculate incidence rate ratios, and logistic regression models were used to calculate odds ratios. Fisher’s exact test was used to compare categorical variables. The Mann-Whitney test was used to compare continuous variables. A non-parametric test for trend was used to assess change in proportion over time and stratified by hospital (using the \textit{npt_s} command in STATA).
3.3 Results

All 20 provincial hospitals in northeast Thailand were contacted to participate in this study. Agreement was obtained from 15 (75%) hospitals, of which 10 had microbiological laboratory and hospital databases as electronic files in a readily accessible format (Appendix B.3). Of the 10 hospitals included in the analysis, 3 (30%) had data available for the period 2004–2010, 1 (10%) between 2006–2010, 2 (20%) between 2007–2010, 3 (30%) between 2008 and 2010, and 1 (10%) between 2009–2010 (Table 3.1 and Table 3.2). The median bed number was 450 beds (range 300 to 1,000 beds). A total of 1,969,474 admission records from 1,372,446 patients were evaluated, of which 21,438 (1.1%) admission records had at least one blood culture positive for pathogenic organisms during admission.

A total of 3,451 (16.1%) episodes were defined as hospital-acquired bacteraemia (HAB), 2,302 (10.7%) episodes were healthcare-associated bacteraemia (HCAB) and 15,685 (73.2%) episodes were community-acquired bacteraemia (CAB). Multiple episodes of HAB and HCAB were noted in 26 and 102 patients, respectively. Only the first episodes of HAB and HCAB in 3,424 and 2,184 patients, respectively, were included in further analysis.

3.3.1 Incidence of HAB and HCAB

The average incidence rate for HAB during the 7-year study period was 0.7 per 1,000 patient-days, with an overall increase in rate over time. The incidence rate of HAB increased from 0.6 in 2004 to 0.8 per 1,000 patient-days in 2010 (p<0.001) (Table 3.1).
**Table 3.1:** Incidence rate of hospital-acquired bacteremia (HAB) and associated death rate between 2004 and 2010 in northeast Thailand

<table>
<thead>
<tr>
<th>Year</th>
<th>Total number of hospitals with available data</th>
<th>Total number of hospital admissions</th>
<th>Total number of hospital admissions at risk of HAB*</th>
<th>Total number of patients with HAB</th>
<th>Deaths associated with HAB</th>
<th>30-day mortality associated with HAB</th>
<th>Incidence rate for HAB (per 1,000 patient-days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>3</td>
<td>129,376</td>
<td>74,272</td>
<td>212</td>
<td>90</td>
<td>42.5%</td>
<td>0.6</td>
</tr>
<tr>
<td>2005</td>
<td>3</td>
<td>138,816</td>
<td>79,254</td>
<td>292</td>
<td>120</td>
<td>41.1%</td>
<td>0.8</td>
</tr>
<tr>
<td>2006</td>
<td>4</td>
<td>187,812</td>
<td>102,948</td>
<td>259</td>
<td>100</td>
<td>38.6%</td>
<td>0.5</td>
</tr>
<tr>
<td>2007</td>
<td>6</td>
<td>241,208</td>
<td>129,574</td>
<td>366</td>
<td>185</td>
<td>50.5%</td>
<td>0.6</td>
</tr>
<tr>
<td>2008</td>
<td>9</td>
<td>372,564</td>
<td>199,154</td>
<td>640</td>
<td>281</td>
<td>43.9%</td>
<td>0.7</td>
</tr>
<tr>
<td>2009</td>
<td>10</td>
<td>453,791</td>
<td>239,814</td>
<td>840</td>
<td>388</td>
<td>46.2%</td>
<td>0.8</td>
</tr>
<tr>
<td>2010</td>
<td>10</td>
<td>445,907</td>
<td>244,427</td>
<td>815</td>
<td>395</td>
<td>48.5%</td>
<td>0.8</td>
</tr>
<tr>
<td>Overall</td>
<td>10</td>
<td>1,969,474</td>
<td>1,069,443</td>
<td>3,424</td>
<td>1,559</td>
<td>45.5%</td>
<td>0.7</td>
</tr>
</tbody>
</table>

* Patients at risk of HAB were patients who stayed in the hospital longer than 2 days.
Of 1,969,474 admission records, 119,286 (10.1%) had a hospital stay within 30 days prior to admission and were at risk of HCAB. The cumulative incidence for HCAB during the 7-year study period was 1.8 per 100 readmissions, with an overall increase in the cumulative incidence over time. The cumulative incidence of HCAB increased from 1.2 in 2004 to 2.0 per 100 readmissions in 2010 (p<0.001) (Table 3.2). The incidence rate of HAB and HCAB varied by hospitals (Appendix B.4), but the overall increasing trends were observed in most hospitals.

3.3.2 Demographic risk factors for HAB and HCAB

Of 3,424 patients with a primary episode of HAB, 2,000 (58.4%) were male and 1,424 (41.6%) were female. The median age was 51 years (interquartile range [IQR] 16–67 years, range 0–88 years). The median time from hospital admission to bacteraemia was 8 days (IQR 4–15 days, range 3–105 days). The median length of stay for patients with HAB was longer than patients who were at risk of, but did not develop HAB (18 vs. 4 days, p<0.001). The overall incidence rate of HAB was higher in males than in females (0.8 vs. 0.6 per 1,000 patient-days, incidence rate ratio [IRR] 1.21; 95% confidence interval [CI] 1.13 to 1.30, p<0.001) (Figure 3.1). The incidence rates of HAB were highest in infants (1.1 per 1,000 patient-days), and in those older than 80 years of age (0.9 per 1,000 patient-days).
### Table 3.2: Cumulative incidence of healthcare-associated bacteremia (HCAB) and associated death rate between 2004 and 2010 in northeast Thailand

<table>
<thead>
<tr>
<th>Year</th>
<th>Total number of hospitals with available data</th>
<th>Total number of hospital admission</th>
<th>Total number of hospital admission at risk of HCAB*</th>
<th>Total number of patients with HCAB</th>
<th>Deaths associated with HCAB</th>
<th>30-day mortality associated with HCAB</th>
<th>Cumulative incidence for HCAB (per 100 readmissions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>3</td>
<td>129,376</td>
<td>7,259</td>
<td>86</td>
<td>44</td>
<td>51.2%</td>
<td>1.2</td>
</tr>
<tr>
<td>2005</td>
<td>3</td>
<td>138,816</td>
<td>8,266</td>
<td>125</td>
<td>41</td>
<td>32.8%</td>
<td>1.5</td>
</tr>
<tr>
<td>2006</td>
<td>4</td>
<td>187,812</td>
<td>10,960</td>
<td>157</td>
<td>68</td>
<td>43.3%</td>
<td>1.4</td>
</tr>
<tr>
<td>2007</td>
<td>6</td>
<td>241,209</td>
<td>14,234</td>
<td>272</td>
<td>117</td>
<td>43.0%</td>
<td>1.9</td>
</tr>
<tr>
<td>2008</td>
<td>9</td>
<td>372,564</td>
<td>22,601</td>
<td>435</td>
<td>198</td>
<td>45.5%</td>
<td>1.9</td>
</tr>
<tr>
<td>2009</td>
<td>10</td>
<td>453,790</td>
<td>26,969</td>
<td>527</td>
<td>206</td>
<td>39.1%</td>
<td>2.0</td>
</tr>
<tr>
<td>2010</td>
<td>10</td>
<td>445,907</td>
<td>28,997</td>
<td>582</td>
<td>239</td>
<td>41.1%</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td><strong>10</strong></td>
<td><strong>1,969,474</strong></td>
<td><strong>119,286</strong></td>
<td><strong>2,184</strong></td>
<td><strong>913</strong></td>
<td><strong>41.8%</strong></td>
<td><strong>1.8</strong></td>
</tr>
</tbody>
</table>

*Patients at risk of HCAB were patients who had a hospital stay within 30 days prior to the admission.*
Figure 3.1: Age- and gender-specific incidence rate of hospital-acquired bacteraemia (HAB) between 2004 and 2010 in northeast Thailand

Of 2,184 patients with a primary episode of HCAB, 1,166 (53.4%) were male and 1,018 (46.6%) were female. Median age was 57 years (IQR 41–70 years, range 0–89 years). The median time between prior and study admission was 11 days (IQR 6–19 days, range 1–30 days). The median length of stay for patients with HCAB was longer than patients who were at risk of, but did not present with HCAB (6 vs. 3 days, p<0.001). Male gender was associated with a higher risk of HCAB (odds ratio [OR] 1.29; 95%CI 1.18 to 1.40, p<0.001) (Figure 3.2). The incidence rates of HCAB were high in infants (1.1 per 100 readmission), and very high in those older than 30 years of age (Figure 3.2).
3.3.3 Pathogenic organisms associated with HAB and HCAB

Of all pathogenic organisms causing HAB, 2,313 (67.6%) were Gram-negative bacteria, 885 (25.8%) were Gram-positive bacteria, 81 (2.4%) were fungi, 3 (0.1%) were Mycobacterium spp., and 141 (4.1%) were polymicrobial (Table 3.3). The most common pathogens identified were Acinetobacter spp. (16.2%), Klebsiella pneumoniae (13.9%), Staphylococcus aureus (13.9%), Escherichia coli (12.6%), and Pseudomonas spp. (10.5%). Amongst S. aureus HABs, the proportion of meticillin-resistant S. aureus (MRSA) was 37.0% (176/476). Corresponding proportions of extended-spectrum β-lactamase (ESBL)-producing E. coli and K. pneumoniae were 38.9% (169/434) and 59.3% (283/477), respectively.
Table 3.3: Pathogenic organisms isolated from 3,424 patients with primary episode of hospital-acquired bacteraemia (HAB) and 2,184 patients with primary episode of healthcare-acquired bacteraemia (HCAB) in northeast Thailand between 2004 and 2010

<table>
<thead>
<tr>
<th>Organisms</th>
<th>HAB</th>
<th>HCAB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gram negative bacteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2,313 (67.6%)</td>
<td>1,470 (67.3%)</td>
</tr>
<tr>
<td><em>Acinetobacter</em> spp.</td>
<td>554 (16.2%)</td>
<td>124 (5.7%)</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESBL –ve</td>
<td>265 (7.7%)</td>
<td>400 (18.3%)</td>
</tr>
<tr>
<td>ESBL +ve</td>
<td>169 (4.9%)</td>
<td>175 (8.0%)</td>
</tr>
<tr>
<td><em>Klebsiella pneumoniae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESBL –ve</td>
<td>194 (5.7%)</td>
<td>141 (6.5%)</td>
</tr>
<tr>
<td>ESBL +ve</td>
<td>283 (8.3%)</td>
<td>70 (3.2%)</td>
</tr>
<tr>
<td><em>Enterobacter</em> spp.</td>
<td>122 (3.6%)</td>
<td>55 (2.5%)</td>
</tr>
<tr>
<td><em>Pseudomonas</em> spp.</td>
<td>358 (10.5%)</td>
<td>205 (9.4%)</td>
</tr>
<tr>
<td>Other Gram negative</td>
<td>213 (6.2%)</td>
<td>256 (11.7%)</td>
</tr>
<tr>
<td><strong>Gram positive</strong></td>
<td>885 (25.8%)</td>
<td>592 (27.1%)</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meticillin-susceptible</td>
<td>312 (9.1%)</td>
<td>238 (10.9%)</td>
</tr>
<tr>
<td>Meticillin-resistant</td>
<td>164 (4.8%)</td>
<td>67 (3.1%)</td>
</tr>
<tr>
<td><em>Enterococcus</em> spp.</td>
<td>173 (5.1%)</td>
<td>74 (3.4%)</td>
</tr>
<tr>
<td>Other Gram positives</td>
<td>236 (6.9%)</td>
<td>213 (9.8%)</td>
</tr>
<tr>
<td><strong>Fungi</strong></td>
<td>81 (2.4%)</td>
<td>24 (1.1%)</td>
</tr>
<tr>
<td><em>Cryptococcus</em> spp.</td>
<td>16 (0.5%)</td>
<td>20 (0.9%)</td>
</tr>
<tr>
<td><em>Candida</em> spp.</td>
<td>59 (1.7%)</td>
<td>4 (0.2%)</td>
</tr>
<tr>
<td><em>Penicillium</em> spp.</td>
<td>6 (0.2%)</td>
<td>-</td>
</tr>
<tr>
<td><em>Histoplasma</em> spp.</td>
<td>1 (0.0%)</td>
<td>-</td>
</tr>
<tr>
<td><em>Mycobacterium</em> spp.</td>
<td>3 (0.1%)</td>
<td>4 (0.2%)</td>
</tr>
<tr>
<td>Polymicrobial infections</td>
<td>141 (4.1%)</td>
<td>94 (4.3%)</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>3,424 (100.0%)</td>
<td>2,184 (100.0%)</td>
</tr>
</tbody>
</table>
Of all pathogenic organisms causing HCAB, 1,470 (67.3%) were Gram-negative bacteria, 592 (27.1%) were Gram-positive bacteria, 24 (1.1%) were fungi, 4 (0.2%) were *Mycobacterium* spp., and 94 (4.3%) were polymicrobial (Table 4.3.3). The most common pathogens identified were *E. coli* (26.3%), *S. aureus* (14.0%), *K. pneumoniae* (9.7%), *Pseudomonas* spp. (9.4%) and *Acinetobacter* spp. (5.7%). The proportion of ESBL-producing *E. coli*, ESBL-producing *K. pneumoniae* and MRSA were 30.4% (175/575), 33.2% (70/211), and 24.3% (74/305), respectively.

There were no differences in the patterns of common pathogens identified among different provinces or over the study period (Appendix B.5 and Appendix B.6). However, there was an overall increase in the proportions of ESBL-producing *E. coli* over time. From 2004 to 2010, the proportion of ESBL-producing *E. coli* causing HAB rose from 33.3% (10/30) to 51.5% (51/99) (p = 0.005) (Appendix B.7 and Appendix B.8), and that causing HCAB rose from 20.8% (5/24) to 32.9% (48/146) (p < 0.001) (Appendix B.8 and Appendix B.9). The rising trend of ESBL-producing *E. coli* was observed in most hospitals, while a clear overall trend in the proportions of ESBL-producing *K. pneumoniae* or MRSA was not observed (Appendix B.10 and Appendix B.11).

### 3.3.4 Mortality associated with HAB and HCAB

Death within 30-days of the positive blood culture taken was identified in 1,559 patients with HAB, giving an overall 30-day mortality of 45.5% (Table 3.1). Considering all patients who were admitted for more than 2 days, the 30-day mortality of those with HAB was higher than those without HAB (45.5% [1,559/3,424] vs. 5.5% [45,807/833,818], p < 0.001). Death in HAB patients occurred rapidly, with 749 of 1,559 deaths (48.0%) occurring within two days of the bacteraemia, 89 (5.7%) on day 3, and 74 (4.8%) on day 4. Death in HAB patients occurred in hospital in 58.4% (911/1,559) of cases, the reminder occurring after hospital discharge. There was no change in the 30-day mortality associated with HAB over time (p = 0.58).
Death within 30 days of admission with an episode of HCAB was identified in 913 patients, giving an overall 30-day mortality of 41.8% (Table 3.2). Considering all patients who had a hospital stay within 30 days prior to the admission, the mortality of those with HCAB was significantly higher than those without HCAB (41.8% [913/2,184] vs. 13.0% [15,168/117,102], p<0.001). Death in HCAB patients also occurred rapidly, with 410 of 913 deaths (45.7%) occurring within the first two days of admission, 54 (6.0%) on day 3, and 46 (5.1%) on day 4. Death in HCAB patients occurred in hospital in 43.2% (394/913) of cases, the reminder occurring after hospital discharge. There was no change in the 30-day mortality associated with HCAB over time (p = 0.36).

3.4 Discussion

This study showed that nosocomial infection is an increasing and important problem in northeast Thailand. The total number of deaths associated with HAB and HCAB in 2010 in our study (n = 634) were much higher than the total number of reported deaths due to important notifiable diseases such as dengue hemorrhagic fever (n = 139), influenza (n = 126), and leptospirosis (n = 43) during the same period countrywide. There was a 32.3% increase in the incidence rate of HAB and 66.8% in the cumulative incidence of HCAB between 2004 and 2010 in northeast Thailand. These estimates reinforce the need for improved surveillance and prevention of nosocomial infection in developing countries.

An incidence rate of HAB in the participating hospitals in 2010 of 0.8 per 1,000 patient-days is higher than recent estimates in high-income countries, including 0.7 per 1,000 patient-days in Canada between 2007 and 2010, 0.6 per 1,000 patient-days in the USA in 2005, and 0.6 per 1,000 patient-days in Estonia between 2004 and 2005. The Thai data are consistent with a recent review showing that other parameters used to estimate the burden of nosocomial infection in developing countries, such as prevalence of healthcare associated infections and ICU-acquired infections, are substantially higher than in developed countries. The recent surveillance study conducted by
the International Nosocomial Infection Control Consortium (INICC) also found that rates of central line associated bloodstream infection (CLAB) were significantly higher in ICUs in developing countries (6.8 per 1,000 central line-days) versus those reported in US ICUs (2.0 per 1,000 central line-days).[122]

Our HAB incidence rate is, however, lower than HAB rates reported through active surveillance in some developing countries, including 1.0 per 1,000 patient-days in Kenya between 2002 - 2009,[111] and 1.2 per 1,000 patient-days in Iran in 2006.[112] It is possible that active surveillance may improve the detection of HAB and nosocomial infection in our geographical region.

During the study period, Acinetobacter spp. was the most common pathogen associated with HAB, followed by K. pneumoniae and S. aureus. Acinetobacter spp. is increasingly recognized as an important cause of nosocomial infection,[123] and our study confirms the importance this species as a leading cause of nosocomial infection in developing tropical countries.[3, 111, 124] The proportion of MRSA causing HAB in our setting (37%) was higher than that reported from developed countries,[119, 121, 125] and is consistent with a previous review of developing countries. An increase in the proportion of ESBL-producing E. coli causing HAB in our study is alarming, and is consistent with our previous report of an increase in the proportion of ESBL-producing organisms causing CAB in the same setting.[113]

This study highlights an increasing incidence of HCAB in developing countries. We used the total number of patients with readmission as a denominator to estimate the cumulative incidence of HCAB rather than the total number of patients with bacteremia.[59, 115, 126] Our estimates showed that healthcare-associated infection was an increasing cause of readmission. The high proportion of MRSA, ESBL-producing E. coli and ESBL-producing K. pneumoniae amongst organisms causing HCAB was relatively similar to that causing HAB. Much lower resistance levels were seen in organisms causing CAB.[113] This is consistent with previous reports of HCAB in developed countries.[8, 9, 19]

The observed increase in incidence of both HAB and HCAB could be due to a combination of an increase in the incidence of nosocomial infection associated with a rise in the number of at-risk
patients (for example aging patients and those with invasive interventions), and an increase in
detection of HAB and HCAB due to improved healthcare practice over time. There is evidence that
the incidence rate of CLAB in developing countries can be substantially reduced using a multi-
dimensional infection control approach including a bundle of interventions, education, outcome
surveillance, process surveillance, feedback on CLAB rate and performance feedback.\textsuperscript{127-133}

The overall 30-day mortality with HAB of 45.5% in our setting is much higher than that typically
reported in high-income countries,\textsuperscript{119, 121, 134} but lower than the reported in-hospital mortality of 53%
from a rural district hospital in Kenya.\textsuperscript{111} The overall 30-day mortality with HCAB of 41.8% in our
setting is also much higher than typically seen in high-income countries.\textsuperscript{59, 115, 126} In addition
to patient-related factors, the higher mortality typically seen in developing countries may be related to
the proportion of antimicrobial-resistant pathogens, empirical antibiotic regimens used, and sub-
optimal severe sepsis management in resource-limited settings.\textsuperscript{111, 135} It is also possible that practice
in high-income countries can detect milder bacteraemia cases such as cases due to intravenous device
that is then rapidly removed, while the practice in low-income countries may be less likely to achieve
this. The high mortality observed in our study also reflects post-discharge ascertainment of patient
outcomes using the national death registry. We found that in 47.2% of fatal cases of HAB or HCAB
death occurred after hospital discharge. This reflects a preference amongst people in the study area
to die at home. Further studies need to explore how to reduce the mortality of patients with HAB and
HCAB in resource-limited areas.

A limitation of this study is that more complete clinical data were not available. As data on central
line days were not available, the incidence rate of CLAB per 1,000 central line days could not be
estimated and benchmarked against other prospective studies.\textsuperscript{136-153} As data on process surveillance
were not available, the reasons for the increased incidence of HAB could not be systematically
assessed.\textsuperscript{138, 147, 154, 155} Another potential limitation is that blood cultures may not have been
performed for all patients with a likelihood of nosocomial infection, and this might lead to
an underestimation in the incidence of HAB and HCAB among participating hospitals. In addition, data on hospitalisation in other hospitals not participating in the study (for example, a district hospital or a private hospital in the province) were not available, which could have resulted in an underestimation of the incidence of HAB and HCAB in our study. It is also possible that some patients with HAB and HCAB in our study may have had contaminated cultures and were incorrectly counted. However, the high mortality in patients with HAB and HCAB suggested that true infection was more likely than culture contamination. Although our data showed that, in general, patients with HAB and HCAB stayed in the hospital longer than those without, the analysis did not take account of the high mortality associated with HAB and HCAB. The length of stay would be further extended if death of patients with HAB and HCAB could be reduced. Additional costs and extra length of stay attributable to HAB and HCAB will be further evaluated using health economic models,[156, 157]

Although monitoring of nosocomial infection in developing countries is hampered by incomplete routine notification, our study has shown that careful evaluation of readily available routinely collected databases can provide valuable information on the incidence and trend of HAB and HCAB. The methodology used in our study could be applied to other geographical areas where microbiological facilities are available to provide a more comprehensive global picture of the importance of nosocomial infection as a cause of death.

3.5 Conclusions

This study demonstrates a high and increasing incidence of HAB and HCAB in northeast Thailand. Gram-negatives were the most common organisms, and about half of all bacteraemias were caused by multi-drug resistant organisms with increasing proportions of ESBL-producing isolates, and very high associated mortality. Acinetobacter spp. is currently the most common cause of HAB in Thailand.
In some cases, information on nosocomial infection in developing countries can be obtained by integrating readily available databases. Linking routine clinical and laboratory databases can lead to a better understanding of the burden of HAI and help infection-control practitioners better target their efforts to reduce the incidence of HAI and associated mortality. Nosocomial infection is an increasing problem in Thailand, and effective interventions to combat this problem are needed.
Chapter 4

Application of the theoretical domain framework for behaviour change to explore noncompliance in hand hygiene behaviour among hospital healthcare workers

4.1 Introduction

Hand hygiene is recognized as being amongst the simplest and most cost-effective measures to reduce healthcare-associated infections (HCAIs). Its effectiveness was first demonstrated in the studies of Semmelweis\textsuperscript{[158]} in 1847 where it was shown that cleaning hands of hospital staff with a chlorinated solution led to large reductions in the mortality rate among mothers delivering at the General Hospital of Vienna. More recently, one of the most well-known examples of hand hygiene interventions comes from an observational studies at the University Hospital of Geneva, where reported reductions in HCAIs were associated with big improvements in hand hygiene compliance, which improved progressively from 48% in 1994, to 66% in 1997 by implementing a hospital-wide programme, with special emphasis on bed-side, alcohol-based hand disinfection.\textsuperscript{[18]}

The World Health Organization (WHO) emphasizes the importance of preventing HCAIs by giving priority to the promotion of hand hygiene best practices in health-care settings.\textsuperscript{[89]} This may be particularly important in low and middle income countries (LMICs) which have the highest burden of
disease due to HCAIs, but where well-resourced national hand hygiene campaigns have been lacking.

Poor adherence to recommended hand hygiene measures during routine patient care among healthcare workers (HCWs) remains a major problem, and compliance as low as 4% has been reported. Factors associated with poor hand hygiene compliance have been reported from many observational and intervention studies and include internal and external factors. Internal factors include sex, professional category/role, experience of HCWs, knowledge, belief, attitude, awareness, positive role models, and perception. In contrast, external factors include hospital ward, time of day or week, type and intensity of patient care, type of task, moment for performing hand hygiene, workload, activities with high risk of cross-transmission, understaffing or overcrowding, and a high number of opportunities for hand hygiene per hour of patient care. Almost all of these studies were in developed countries, and few high quality studies come from LMICs.

The underlying reasons for low levels of hand hygiene compliance are poorly understood, and little is known about current knowledge and beliefs amongst HCWs in resource-limited settings about the benefits of hand hygiene and infection control activities or potential obstacles to improving infection control.

Factors in noncompliance for hand hygiene behaviour have recently been studied by applying behavioral theories. Hand hygiene behaviour is influenced by both individual (intrapersonal factors) and institutional (interpersonal and community factors) factors.

The theoretical domain framework (TDF) is a framework of behaviour theories, developed from a synthesis of theories of behaviour change with the aim of systematically identifying psychological and organisational theory relevant to health practitioner clinical behaviour change. Recently, a number of studies have used the TDF to explore the determinants of hand hygiene behaviour.
amongst HCWs. This behavioural approach has also been used to identify key determinants of successful hand hygiene improvement strategies in a systematic review.  

The WHO Guidelines on Hand Hygiene in Health Care have been developed with the ultimate objective of changing the behaviour of individual HCWs to optimize compliance with hand hygiene. A systematic understanding of the drivers of hand hygiene behaviour is needed, particularly in developing countries where the HCAI problems are typically greatest but where there has been little research into hand hygiene behaviour.  

Understanding existing causes of poor hand hygiene compliance and which barriers and enablers need to be addressed is an important requirement for designing a hand hygiene promotion intervention having a good chance of success.

Limited data are available concerning factors associated with poor hand hygiene adherence and interventions to improve hand hygiene practices among HCWs in developing countries. Few studies in resource-limited settings have systematically explored the factors affecting hand hygiene compliance at both the individual and institutional levels. In this study, both barriers and enablers associated with hand hygiene behaviour are systematically explored. The aims are to identify the behavioural determinants—both barriers and enablers—that may affect hand hygiene behaviour of HCWs.

4.2 Methods

4.2.1 Study population

Participants were recruited from HCWs in all wards in a 1000-bed tertiary hospital in northeast Thailand. Only HCWs having direct contact with patients were included (including physicians, nurses, practical nurses, nurse-aids, medical students and student nurses).
Inclusion criteria

HCWs having direct contact with patients who worked in all intensive care units (ICUs) and all inpatient wards.

4.2.2 Study design

A cross-sectional study was conducted. Mixed methods including qualitative and quantitative approaches were employed to systematically explore the determinants of hand hygiene behaviour amongst HCWs. Qualitative methods were employed in focus group discussions and semi-structured interviews, while quantitative methods were employed in a self-administrated questionnaire and direct observation on hand hygiene practices.

Focus group discussions were used to identify interpersonal, institutional and community factors affecting hand hygiene behaviour in each HCW group. Semi-structured interviews were used to identify interpersonal, institutional and community factors including organizational factors. A self-administrated questionnaire was used to address knowledge and beliefs about hand hygiene in the entire population of hospital HCWs with patient contact. Direct observation was used to assess the current practice of hand hygiene behaviour from selected HCWs.

4.2.3 Ethical review and study permissions

The ethics committees of the hospital site and the Faculty of Tropical Medicine, Mahidol University approved the research protocol and all study forms (Appendix C.1). The director of the hospital site approved the research plan and gave permission to conduct the study.
4.2.4 Study procedure

The study procedure consisted of four sections: i) documentation preparation, ii) sampling and recruitment, iii) data collection, and iv) data analysis.

Documentation preparation

Documents were prepared for the focus group discussions, semi-structured interviews, self-administrated questionnaire, and direct observations. All documents were developed in the Thai language.

Preparing documents included the following steps:

1) Reviewing international guidelines for hospital hand hygiene and the literature on factors affecting hand hygiene compliance; reviewing the TDF definitions on healthcare professional behaviours.[169]

2) Ensuring that questions on documents were based on applying TDF and the previously described barriers and enablers to hand hygiene practice based on previous reviews.

3) Working with the infection control team (ICT) of the hospital site to ensure that all questions were appropriate in this setting.

4) Developing an observation form, to enable assessment of current hand hygiene practice in HCWs. This required working with the infection control team (ICT) at the hospital site to create a form which can be feasibly applied for the routine work of ICT as well as for the purpose of this study. Hand hygiene opportunities were defined according to the WHO Hand Hygiene Guidelines, [29] and classified as one of five moments for hand hygiene according to these guidelines.

5) Piloting the form amongst a sample of participants (n=30) working at the study site. Piloting indicated that providers clearly understood the form, and no changes were necessary.

6) Submitting all documents including the protocol, informed consent form, participant information sheet, form for hand hygiene observation and proposed questionnaire.
(including a questionnaire for the focus group discussion, questionnaire for the semi-structured interviews, and the self-administrated questionnaire) to the relevant ethical committee.

**Sampling and recruitment**

i. A list of HCWs was provided by the hospital’s Human Resources department. Recruitment documents (including an invitation letter, study information, an informed consent form, and a questionnaire) were sent to all eligible HCWs at all wards including 16 ICUs and 36 non-ICU in-patient wards. HCWs, who voluntarily agreed to participate in the study and signed the informed consent form, were included in the study. Participants who refused to participate in the study or refused to sign the informed consent form were excluded.

ii. For the self-administrated questionnaire, all participants who agreed to sign the informed consent form and complete the questionnaire were recruited.

iii. For focus groups, ten wards from four departments were purposively sampled to obtain a diverse range of participants in term of their professional role and clinical areas in which they worked. One representative of each type of HCW (including physicians, registered nurses (RNs), infection control ward nurses (ICWNs), and nurse-aides) joined in the focus group discussions.

iv. For semi-structured interviews, five selected key administrators, (including the director of the hospital, head of hospital infection control, head of laboratory, and attending physician), who were working in infection control at the hospital were invited to be participants.

v. Observations of hand hygiene practices were performed in the same wards as those used in focus groups discussion. Participants in observational activities were selected by choosing 6 HCWs of each job category including physicians, nurses, practical nurses, nurse-aides, medical students and student nurses working in that ward.
Data collection
i. The questionnaire survey was conducted during November 2010 to January 2011.

ii. The focus group discussion and semi-structured interviews were undertaken over a period of six months from April 2011. Focus group discussion and interviews were conducted in Thai and observed by members of the hospital ICT. Informed consent was obtained before starting each focus group and interview. HCWs that voluntarily agreed to participate in the study and signed the informed consent form were included in the study. Participants who refused to participate in the study or refused to sign the informed consent form were excluded. Participants were interviewed in their work place, in a private area which only the research team could access. Focus groups took place in a meeting room at the study site. Focus groups and interviews were noted on the form and recorded on audiotape.

iii. Observation of hand hygiene practices were performed in the same wards as those used in the focus groups discussion. Observations were performed by trained observers with a clear understanding of the WHO guidelines for hand hygiene. Before collecting data, Cohen’s kappa (for two raters) was used to assess inter-rater reliability. Results from the observations were entered into an observation form derived from the WHO Hand Hygiene Guidelines. One opportunity of hand hygiene counted as one observation. Results from the observations were entered into an observation form derived from WHO Hand Hygiene Guidelines. The observations were conducted during February to April 2011.

iv. The questionnaire consisted of three parts: the first part was concerned with general information; the second part contained questions to assess current knowledge; and the last part contained questions to assess beliefs about hand hygiene following the TDF. Questions regarding personal knowledge were derived from hand hygiene knowledge questionnaires from the WHO guideline for hand hygiene. Hand hygiene knowledge questionnaires had 8 scale items and scores between 0 and 25. Likert scales with five points were used to capture each participant’s degree of agreement with a statement (1 = strongly disagree, 5 = strongly
agree). There were 16 questions with these scale items and total scores could range between 16 and 80.

v. The focus group discussions made use of five open-ended questions to assess culture and group behavior of HCWs towards infection control and hand hygiene practice. The contents of the interviews covered five mains issues including: (i) current hand hygiene practice, (ii) reasons for performing hand hygiene, (iii) guidelines on hand hygiene, (iv) obstacles/barriers for hand hygiene practices, and (v) promotions or campaigns to improve hand hygiene.

vi. The semi-structured interviews consisted of six open-ended questions to assess obstacles to improving infection control and hand hygiene. The contents of the interview covered six mains issues: (i) effective infection control, (ii) knowledge about hand hygiene practice, (iii) attitude toward hand hygiene, (iv) resources, (v) organizational authority of hospital infection control department, and (vi) monitoring and feedback system on infection control.

vii. Hand hygiene observations were recorded in the observation form provided in the WHO guidelines for hand hygiene. [30]

Example questions of each form for capturing the 14 TDF domains are shown in Appendix C.2.

Data analysis

Analysis was performed for both the quantitative data (including data from questionnaire and observations) and for qualitative data (including data from focus groups and interviews).

Quantitative data

Descriptive statistics were used to describe general characteristics of HCWs' current knowledge and current hand hygiene practices. Estimates of internal consistency were calculated for theoretical domains and factors using Cronbach’s alpha with a cutoff of 0.60 which is considered sufficient for preliminary research.[172] Domain scores were based on responses measured on a five-point Likert scale. For negatively worded items, the scale scores were reversed. A mean score of each domain was
used in the analysis. For identifying barriers and enablers to good hand hygiene practice, a low mean value was taken to suggest that a particular domain may be a barrier, and a high mean value was taken to suggest that it may be an enabler.

Pearson’s correlation coefficients were used to assess correlations between domain scores; these were defined as weak (0.0 to 0.39), moderate (0.40 to 0.69), or strong (0.70 to 1.0). All analysis was performed using STATA version 14.0 (StataCorp LP, College station, Texas).

Qualitative data

All text data were directly recorded by audiotape and by manual writing on forms. The recordings were transcribed verbatim and transcriptions verified prior to analysis. All the data were analyzed line-by-line until a clear sense of the relationship among the themes emerged. Content analysis was applied using the TDF themes for analysis. The set of transcript data was analyzed following six steps:

1) Coding and describing transcripts

The 14 TDF domains were taken from standard definitions (Appendix C.2) to classify “utterances” (coded interview quotes) from the transcript. The coding scheme was generated as guidance to ensure consistency in coding. Each transcript was coded into the 14 TDF domains.

2) Generating specific data

Specific beliefs were generated for each utterance in all TDF domains. A specific belief is “a collection of participant responses with a similar underlying theme that suggests a problem and/or influence on the target behaviour”.[88]

3) Identification of relevant theoretical domains

Identification and classification of specific data into constructs of each TDF definition was performed. The approach to identification was adapted from Bocart et al., which used psychological theory to inform the choice of methods to implement a hand hygiene
intervention. An example question for each theoretical construct represented within each domain is presented in Table 4.1.

Table 4.1: The theoretical constructs used to analyses text data and example questions

<table>
<thead>
<tr>
<th>Theoretical constructs represented within each domain</th>
<th>Example questions to analyses text a</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TDF 1: Knowledge</strong></td>
<td></td>
</tr>
<tr>
<td>Knowledge (including knowledge of condition /scientific rationale)</td>
<td>Can you describe the guidelines to perform proper hand hygiene?</td>
</tr>
<tr>
<td>Procedural knowledge</td>
<td>Can you discuss when to perform hand hygiene?</td>
</tr>
<tr>
<td>Knowledge of task environment</td>
<td>Can you describe why you should be performing hand hygiene?</td>
</tr>
<tr>
<td></td>
<td>Can you describe how the IC team/ICWN works?</td>
</tr>
<tr>
<td></td>
<td>Do you know what information the IC team/ICWN can collect?</td>
</tr>
<tr>
<td><strong>TDF 2: Skills</strong></td>
<td></td>
</tr>
<tr>
<td>Skills</td>
<td>Can you explain the proper procedure of performing hand hygiene?</td>
</tr>
<tr>
<td>Skills development</td>
<td></td>
</tr>
<tr>
<td>Competence</td>
<td>How easy or difficult is it to perform hand hygiene on your unit?</td>
</tr>
<tr>
<td>Ability</td>
<td></td>
</tr>
<tr>
<td>Interpersonal skills</td>
<td>Can you describe how to use the ____?</td>
</tr>
<tr>
<td>Practice</td>
<td>Do you know how to respond when the IC team/ICWN reminds you?</td>
</tr>
<tr>
<td>Skill assessment</td>
<td></td>
</tr>
<tr>
<td><strong>TDF 3: Social/ professional role and identity</strong></td>
<td></td>
</tr>
<tr>
<td>Professional identity</td>
<td>What role will the IC team/ICWN play in enhancing hand hygiene?</td>
</tr>
<tr>
<td>Professional role</td>
<td></td>
</tr>
</tbody>
</table>

a Theoretical constructs applied from Michie, et al. 2014.
b Example questions are adapted from Boscart, et al. 2012.

TDF = Theoretical Domains Framework; IC = infection control; ICWN = infection control ward nurse
Table 4.1: The theoretical constructs used to analyses text data and example questions (cont.)

<table>
<thead>
<tr>
<th>Theoretical constructs</th>
<th>Example questions to analyses text b</th>
</tr>
</thead>
<tbody>
<tr>
<td>represented within each domain a</td>
<td></td>
</tr>
<tr>
<td><strong>TDF 3: Social/professional role and identity</strong></td>
<td></td>
</tr>
<tr>
<td>Social identity</td>
<td>Do you think the IC team/ICWN should determine how you</td>
</tr>
<tr>
<td>Identity</td>
<td>perform hand hygiene?</td>
</tr>
<tr>
<td>Professional boundaries</td>
<td>Do you feel that the guidelines for performing hand hygiene</td>
</tr>
<tr>
<td>Professional confidence</td>
<td>with the IC team/ICWN are congruent with your</td>
</tr>
<tr>
<td>Group identity</td>
<td>professional standard of practice?</td>
</tr>
<tr>
<td>Leadership</td>
<td>Should proper hand hygiene be practiced at all levels of</td>
</tr>
<tr>
<td>Organizational commitment</td>
<td>staff?</td>
</tr>
<tr>
<td><strong>TDF 4: Beliefs about capabilities</strong></td>
<td></td>
</tr>
<tr>
<td>Self-confidence</td>
<td>How difficult or easy is it for you to maintain proper hand</td>
</tr>
<tr>
<td>Perceived competence</td>
<td>hygiene?</td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>What problems have you encountered when trying to practice</td>
</tr>
<tr>
<td>Perceived behavioural control</td>
<td>proper hand hygiene?</td>
</tr>
<tr>
<td>Beliefs</td>
<td>What would help you to increase hand hygiene compliance?</td>
</tr>
<tr>
<td>Self-esteem</td>
<td>How confident are you that you can increase compliance with</td>
</tr>
<tr>
<td>Empowerment</td>
<td>the barriers and difficulties you face?</td>
</tr>
<tr>
<td>Professional confidence</td>
<td>How well equipped and comfortable do you feel in increasing</td>
</tr>
<tr>
<td></td>
<td>your level of hand hygiene compliance?</td>
</tr>
<tr>
<td></td>
<td>When using the IC team/ICWN?</td>
</tr>
<tr>
<td></td>
<td>How capable do you feel in maintaining increased compliance</td>
</tr>
<tr>
<td></td>
<td>with hand hygiene? When using the IC team/ICWN?</td>
</tr>
<tr>
<td></td>
<td>How well will this the IC team/ICWN record your hand</td>
</tr>
<tr>
<td></td>
<td>hygiene?</td>
</tr>
</tbody>
</table>

a Theoretical constructs applied from Michie, et al. 2014.

b Example questions are adapted from Boscart, et al. 2012.

TDF = Theoretical Domains Framework; IC = infection control; ICWN = infection control ward nurse
<table>
<thead>
<tr>
<th>Theoretical constructs</th>
<th>Example questions to analyses text $^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TDF 5: Optimism</strong></td>
<td></td>
</tr>
<tr>
<td>Optimism</td>
<td>Does HCW wash their hand every time required for hand hygiene?</td>
</tr>
<tr>
<td>Pessimism</td>
<td></td>
</tr>
<tr>
<td>Unrealistic optimism</td>
<td></td>
</tr>
<tr>
<td>Identity</td>
<td></td>
</tr>
<tr>
<td><strong>TDF 6: Beliefs about consequences</strong></td>
<td></td>
</tr>
<tr>
<td>Beliefs</td>
<td>Does hand hygiene play an important role in your current practice? For yourself? For your patients? Can you explain why?</td>
</tr>
<tr>
<td>Outcome expectancies</td>
<td>Do you believe that the IC team/ICWN will play an important role in your practice?</td>
</tr>
<tr>
<td>Characteristics of outcome expectancies (physical, social, emotional)</td>
<td>How will you feel if you are able to increase hand hygiene compliance? How will you feel if you do not?</td>
</tr>
<tr>
<td>Anticipated regret</td>
<td>Do you foresee any positive or negative outcomes of increased hand hygiene compliance on patient outcomes? Staff outcomes? Do you foresee these outcomes/consequences as long term or short term? Do you foresee a negative consequence of using the IC team/ICWN? For patient outcomes? Staff outcomes? What do you think will happen if hand hygiene compliance is not increased in terms of patient outcomes? Staff outcomes? Do you think these are short- or long-term consequences?</td>
</tr>
</tbody>
</table>

$^a$ Theoretical constructs applied from Michie, et al. 2014.

$^b$ Example questions are adapted from Boscart, et al. 2012.

TDF = Theoretical Domains Framework; IC = infection control; ICWN = infection control ward nurse
Table 4.1: The theoretical constructs used to analyses text data and example questions (cont.)

<table>
<thead>
<tr>
<th>Theoretical constructs</th>
<th>Example questions to analyses text b</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TDF 7: Reinforcement</strong></td>
<td></td>
</tr>
<tr>
<td>Rewards (proximal/distal, valued/not valued, probable/improbable)</td>
<td>Do you feel any reward / punishment can increase your hand hygiene compliance?</td>
</tr>
<tr>
<td>Incentives</td>
<td></td>
</tr>
<tr>
<td>Punishment</td>
<td></td>
</tr>
<tr>
<td>Consequents</td>
<td></td>
</tr>
<tr>
<td>Reinforcement</td>
<td></td>
</tr>
<tr>
<td>Contingencies</td>
<td></td>
</tr>
<tr>
<td>Sanctions</td>
<td></td>
</tr>
<tr>
<td><strong>TDF 8: Intentions</strong></td>
<td></td>
</tr>
<tr>
<td>Stability of intentions</td>
<td>Would you like to increase your hand hygiene compliance?</td>
</tr>
<tr>
<td>Stages of change model</td>
<td>Do you feel a need to increase your hand hygiene compliance?</td>
</tr>
<tr>
<td>Transtheoretical model and stages of change</td>
<td>What are your reasons for increasing your hand hygiene compliance?</td>
</tr>
<tr>
<td></td>
<td>Is there any aspect of your hand hygiene performance that you could improve on? Frequency, activity related?</td>
</tr>
<tr>
<td></td>
<td>Are there other things that you would like to achieve that might interfere with increasing your hand hygiene compliance?</td>
</tr>
<tr>
<td></td>
<td>Are there incentives to increasing hand hygiene compliance? If so, what are they?</td>
</tr>
</tbody>
</table>

a Theoretical constructs applied from Michie, et al. 2014.

b Example questions are adapted from Boscart, et al. 2012.

TDF = Theoretical Domains Framework; IC = infection control; ICWN = infection control ward nurse
Table 4.1: The theoretical constructs used to analyses text data and example questions (cont.)

<table>
<thead>
<tr>
<th>Theoretical constructs</th>
<th>Example questions to analyses text</th>
</tr>
</thead>
<tbody>
<tr>
<td>represented within each domain a</td>
<td></td>
</tr>
</tbody>
</table>

TDF 9: Goals

| Goals (distal/proximal)                        | How will the IC team/ICWN increase hand hygiene compliance? |
| Goal priority                                  | Who needs to work differently for this to occur? When?     |
| Goal/target setting                            | Where?                                                        |
| Goals (autonomous/controlled)                  | How do you know whether increased hand hygiene compliance has occurred? |
| Action planning                                | What do you currently do in term of performing hand hygiene? |
| Implementation intention                      | Is this new or existing behaviour that needs to become a habit? |
|                                                | Can the context be used to prompt you to perform hand hygiene? (prompts: layout, reminders, equipment) |
|                                                | How long do you think the changes are going to take?        |

TDF 10: Memory, attention and decision processes

| Memory                                         | Do you usually perform hand hygiene? How often on a regular shift? |
| Attention                                      | Do you consciously think and make the decision to wash your hands? |
| Attention control                              | What factors influence that decision? Type of care activity? Type of patient? Time? |
| Decision making                                | How much attention do you have to pay to perform hand hygiene? |
| Cognitive overload/tiredness                   |                                                            |

a Theoretical constructs applied from Michie, et al. 2014.
b Example questions are adapted from Boscart, et al. 2012.

TDF = Theoretical Domains Framework; IC = infection control; ICWN = infection control ward nurse
Table 4.1: The theoretical constructs used to analyses text data and example questions (cont.)

<table>
<thead>
<tr>
<th>Theoretical constructs</th>
<th>Example questions to analyses text (^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>represented within each domain (^a)</td>
<td></td>
</tr>
</tbody>
</table>

**TDF 10: Memory, attention and decision processes**
- Do you remember to perform hand hygiene? How?
- Do you think the reminder system in the IC team/ICWN will enhance your hand hygiene?
- Can you think of times where you might not perform hand hygiene, such as competing tasks or time constraints?

**TDF 11: Environmental context and resources**
- **Environmental stressors**: Where do you disinfect your hands?
- **Resources/material resources**: Have you used a wearable alcohol dispenser device? How does this impact your hand hygiene performance?
- **(availability and management)**: To what extent do physical or resource factors, such as the availability and functioning of wall units and technology, facilitate or hinder performing hand hygiene?
- **Organisation culture/climate**: Do you believe that the IC team/ICWN will enhance your hand hygiene performance?
- **Salient events/critical incidents**: What extent do social influences facilitate or hinder performing hand hygiene? Social influence from your peers?
- **Person x environmental interaction**: Will you or have you ever observed others performing hand hygiene?
- **Barriers and facilitators**: Social pressure, Does hand hygiene play an important role on your unit? Can you explain why?
- **Social norms (subjective, descriptive, injunctive norms)**: Do you believe that nursing staff on this unit are washing their hands when necessary?
- **Group conformity**: To what extent do social influences facilitate or hinder performing hand hygiene? Social influence from your peers?
- **Social comparisons**: Will you or have you ever observed others performing hand hygiene?
- **Group norms**: Theoretical constructs applied from Michie, et al. 2014.
- **Power(hierarchy)**: Example questions are adapted from Boscart, et al. 2012.

\(^a\) Theoretical constructs applied from Michie, et al. 2014.

\(^b\) Example questions are adapted from Boscart, et al. 2012.

TDF = Theoretical Domains Framework; IC = infection control; ICWN = infection control ward nurse
Table 4.1: The theoretical constructs used to analyses text data and example questions (cont.)

<table>
<thead>
<tr>
<th>Theoretical constructs represented within each domain</th>
<th>Example questions to analyses text</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TDF 12: Social influences</strong></td>
<td></td>
</tr>
<tr>
<td>Social support</td>
<td>Managers? Other professional groups? Patients? Relatives?</td>
</tr>
<tr>
<td>(personal/professional/organizational, intra/interpersonal, society/community)</td>
<td>Do you believe that there will be social influences from your peers to use the IC team/ICWN? Managers? Patients? Other groups?</td>
</tr>
<tr>
<td>Alienation</td>
<td>Do you have role models in performing hand hygiene? Who?</td>
</tr>
<tr>
<td>Group identity</td>
<td></td>
</tr>
<tr>
<td>Modelling</td>
<td></td>
</tr>
<tr>
<td><strong>TDF 13: Emotion</strong></td>
<td></td>
</tr>
<tr>
<td>Fear</td>
<td>Does performing hand hygiene elicit an emotional response?</td>
</tr>
<tr>
<td>Anxiety</td>
<td>If so, what?</td>
</tr>
<tr>
<td>Affect</td>
<td>To what extent will emotional factors facilitate or hinder your hand hygiene?</td>
</tr>
<tr>
<td>Stress</td>
<td>Do you believe that emotional factors will influence the use of the IC team/ICWN?</td>
</tr>
<tr>
<td>Depression</td>
<td></td>
</tr>
<tr>
<td>Positive/negative affect</td>
<td></td>
</tr>
<tr>
<td>Burn-out</td>
<td></td>
</tr>
<tr>
<td><strong>TDF 14: Behaviour regulation</strong></td>
<td></td>
</tr>
<tr>
<td>Self-monitoring</td>
<td>What initial steps need to be taken to improve hand hygiene compliance/ use the IC team/ICWN on an individual level?</td>
</tr>
<tr>
<td>Breaking habit</td>
<td>How about on an organizational level?</td>
</tr>
<tr>
<td>Action planning</td>
<td>Can you think of any procedures that would encourage increased hand hygiene compliance/ use of the IC team/ICWN?</td>
</tr>
</tbody>
</table>


b Example questions are adapted from Boscart, et al. 2012.

TDF = Theoretical Domains Framework; IC = infection control; ICWN = infection control ward nurse
4) Connecting and interrelating data

Following identification of the relevant theoretical domains, the beliefs were mapped for systematically analyzing interrelations within the behavioural domain into the COM-B system proposed by Michie et al., which considers capability, opportunity and motivation as all determining behaviour\[^{37}\] (Table 4.2). This framework was validated for use in behaviour change and implementation research by Cane et al.\[^{88}\] Capability, which includes having the necessary knowledge and skills, is defined as “the individual’s psychological and physical capacity to engage in the activity concerned”\[^{37}\]. Motivation is defined as “all those brain processes that energize and direct behaviour, not just goals and conscious decision-making”\[^{37}\]. It includes “habitual processes, emotional responding, as well as analytical decision-making”\[^{37}\]. Opportunity is defined as “all the factors that lie outside the individual that make the behaviour possible or prompt it”\[^{37}\].
Table 4.2: Mapping of the Behaviour Change Wheel’s COM-B system to the TDF Domains, from Cane et al., 2012.\(^{[88]}\)

<table>
<thead>
<tr>
<th>COM-B component</th>
<th>TDF Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capability</td>
<td>Psychological</td>
</tr>
<tr>
<td></td>
<td>Skills</td>
</tr>
<tr>
<td></td>
<td>Memory, Attention and Decision</td>
</tr>
<tr>
<td></td>
<td>Behavioural Regulation</td>
</tr>
<tr>
<td></td>
<td>Physical Skills</td>
</tr>
<tr>
<td>Opportunity</td>
<td>Social</td>
</tr>
<tr>
<td></td>
<td>Social Influences</td>
</tr>
<tr>
<td></td>
<td>Environmental Context and Resources</td>
</tr>
<tr>
<td>Motivation</td>
<td>Reflective</td>
</tr>
<tr>
<td></td>
<td>Social/Professional Role &amp; Identity</td>
</tr>
<tr>
<td></td>
<td>Beliefs about Capabilities</td>
</tr>
<tr>
<td></td>
<td>Optimism</td>
</tr>
<tr>
<td></td>
<td>Beliefs about Consequences</td>
</tr>
<tr>
<td></td>
<td>Intentions</td>
</tr>
<tr>
<td></td>
<td>Goals</td>
</tr>
<tr>
<td></td>
<td>Automatic</td>
</tr>
<tr>
<td></td>
<td>Social/Professional Role &amp; Identity</td>
</tr>
<tr>
<td></td>
<td>Optimism</td>
</tr>
<tr>
<td></td>
<td>Reinforcement</td>
</tr>
<tr>
<td></td>
<td>Emotion</td>
</tr>
</tbody>
</table>

5) Interpretation, creating explanatory results

Through the following steps, the set of psychological theories and models was used to represent the constructs from the relevant domains for understanding factors associated with non-compliance behaviour for hand hygiene. The interpretation was given for individual, team, and organizational levels, (Table 4.3) that were likely to influence hand hygiene behaviour of HCW. This identification was important in further steps to design the potential intervention, and based on construct allocations proposed by Michie et al.\(^{[42]}\)
Table 4.3: Constructs in four theoretical domains, illustrating individual, team, and organizational levels, based on construct allocations reported by Michie et al., 2005.[42]

<table>
<thead>
<tr>
<th>Domain</th>
<th>Level</th>
<th>Individual</th>
<th>Team</th>
<th>Organizational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Context and Resources</td>
<td>Environmental stressors</td>
<td>Environmental stressors</td>
<td>Resources/material resources</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Person × environment interaction</td>
<td></td>
<td>(availability and management)</td>
<td></td>
</tr>
<tr>
<td>Social Influences</td>
<td>Social support</td>
<td>Leadership</td>
<td>Organizational climate/culture</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Social pressure</td>
<td>Social comparisons</td>
<td>Change management</td>
<td></td>
</tr>
</tbody>
</table>

4.3 Results

Results are presented in seven parts:

1) Sample characteristics

2) Current knowledge about hand hygiene

3) Current hand hygiene practices

4) Perceived barriers for non-compliance with hand hygiene

5) Current beliefs about hand hygiene behaviour

6) Summary of relevant domain findings by applying the TDF

7) Mapping domain findings to the Behaviour Change Wheel’s COM-B system.
4.3.1 Sample characteristics

Population

All 2,030 HCWs at the hospital were contacted to participate in this part of the study. Agreement was obtained from 1,694 (83.4%) participants who completed the self-administered questionnaire. Of these 1,582 participants were included in the analysis concerning current knowledge, current beliefs, and self-reporting about hand hygiene, while 112 participants were excluded due to incomplete the enrollment set (10 of them signed the informed consent form without completing the questionnaire, 8 of them completed the questionnaire without signing the consent form, and 94 of them did not complete both the questionnaire and the consent form).

Sample of the self-administered questionnaire

Of 1,582, almost half the participants completing the self-administered questionnaire were nurses (47.8%). The rest were auxiliaries (26.9%), nursing students (18.0%), and physicians (7.2%). 1,295 (81.9%) were female and 272 (17.19%) were male. The median number of years participants had spent working at the hospital was 7 (interquartile range [IQR] 2-16 years, range 0–45 years) Characteristics of study population are presented in Table 4.4.

Direct observation of hand hygiene practice

A total of 364 participants were randomly observed to assess current hand hygiene practice. Most observed HCWs were female (70.9 % [258/367]), and registered nurses (32.4% [118/364]). They were distributed across the hospital departments (medicine, surgery, paediatric, and obstetrics and gynecology), and roles (staff physician, registered nurse, nurse aides, medical student, nursing student, and visitor). Half of the observed staff worked in ICU wards (162/364). Mean work year experience in this hospital was 10.2 (IQR 3-14, range 1-27).
Sample of the focus group discussion

A total of 60 participants were approached to participate in six sessions of the focus group discussion, and 32 were recruited for four sessions. The distribution across the hospital, specialties (medicine, surgery), and roles (staff physician, registered nurse, infection control ward nurse, nurse aides) were intentionally representative of each type of HCWs by using of purposive sampling (Appendix C.3). Most participants were female (81.3 % [26/32]) (Table 4.5). Focus group discussions ranged in duration from 55 to 112 minutes, with a mean focus group discussion time of 74 minutes.

Sample of the semi-structured interviews

A total of 10 participants were approached for semi-structured interviews. From these five key informants were recruited. This included key administrators in the hospital including the hospital director and heads of department (medicine, surgery, laboratory) (Appendix C.4). Most participants were male (80.0 % [4/5]). Semi-structured interviews ranged in duration from 45 to 128 minutes, with a mean semi-structured interview time of 64 minutes.

4.3.2 Current knowledge about hand hygiene

All recruited HCWs who completed the self-administered questionnaire were assessed for current knowledge about hand hygiene. The median score for questions about knowledge of hand hygiene was 14 correct answers (IQR 13-16 items, range 0–22) out of a maximum of 25, and the mean knowledge score was similar in different HCW groups. Current knowledge of all participants derived from the questionnaire is presented in Figure 4.1 and Appendix C.5.
Table 4.4: Characteristics of the study population

<table>
<thead>
<tr>
<th>Categories of respondents</th>
<th>Physicians</th>
<th>Nurses</th>
<th>Auxiliaries</th>
<th>Nursing students</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>N of respondents</td>
<td>13</td>
<td>812</td>
<td>458</td>
<td>299</td>
<td>1,582</td>
</tr>
<tr>
<td>Male n</td>
<td>8</td>
<td>42</td>
<td>183</td>
<td>39</td>
<td>272</td>
</tr>
<tr>
<td>Female n</td>
<td>5</td>
<td>770</td>
<td>275</td>
<td>260</td>
<td>1,310</td>
</tr>
<tr>
<td>ICU n *</td>
<td>-</td>
<td>254</td>
<td>116</td>
<td>-</td>
<td>370</td>
</tr>
<tr>
<td>Non-ICU n *</td>
<td>-</td>
<td>471</td>
<td>307</td>
<td>-</td>
<td>778</td>
</tr>
<tr>
<td>Department of Eye Ear Nose Throat n *</td>
<td>-</td>
<td>32</td>
<td>23</td>
<td>-</td>
<td>55</td>
</tr>
<tr>
<td>Department of Obstetrics and Gynecology n *</td>
<td>-</td>
<td>130</td>
<td>73</td>
<td>-</td>
<td>203</td>
</tr>
<tr>
<td>Department of Medicine n *</td>
<td>-</td>
<td>165</td>
<td>94</td>
<td>-</td>
<td>259</td>
</tr>
<tr>
<td>Department of Paediatrics n *</td>
<td>-</td>
<td>119</td>
<td>76</td>
<td>-</td>
<td>195</td>
</tr>
<tr>
<td>Department of Surgery n *</td>
<td>-</td>
<td>363</td>
<td>189</td>
<td>-</td>
<td>552</td>
</tr>
</tbody>
</table>

N = number of respondents of total study population, n = number of respondents in subgroup of study population, ICU = Intensive-care unit

*Information is missing in these items
<table>
<thead>
<tr>
<th>Focus group No.</th>
<th>n</th>
<th>Gender</th>
<th>Age (years)(^a)</th>
<th>Length of service (^b)</th>
<th>Role type</th>
<th>Work area</th>
<th>Work status</th>
</tr>
</thead>
<tbody>
<tr>
<td>FG1</td>
<td>10</td>
<td>10 Females</td>
<td>31 [23-41]</td>
<td>6 [1-11]</td>
<td>Infection control ward nurses</td>
<td>5 ICU</td>
<td>Full-time</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5 Non-ICU</td>
<td></td>
</tr>
<tr>
<td>FG2</td>
<td>10</td>
<td>1 Male, 9 Females</td>
<td>29 [21-40]</td>
<td>3 [0-8]</td>
<td>Registered nurse</td>
<td>5 ICU</td>
<td>Full-time</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5 Non-ICU</td>
<td></td>
</tr>
<tr>
<td>FG3</td>
<td>9</td>
<td>3 Males, 6 Females</td>
<td>40 [30-55]</td>
<td>10 [3-14]</td>
<td>Nursing Assistant</td>
<td>4 ICU</td>
<td>Full-time</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5 Non-ICU</td>
<td></td>
</tr>
<tr>
<td>FG4</td>
<td>3</td>
<td>2 Males, 1 Female</td>
<td>32 [30-37]</td>
<td>5 [3-8]</td>
<td>Nurse aids</td>
<td>2 ICU</td>
<td>Full-time</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 Non-ICU</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Median age in years [range]

\(^b\) Median length work experience in this hospital in years [range]
4.3.3 Current hand hygiene practices

Current hand hygiene practices were assessed in two parts: i) self-reporting on hand hygiene practice from the questionnaire survey, and ii) current hand hygiene practice from direct observation.

Self-reporting on hand hygiene practice from questionnaire survey

Out of 1,582 HCWs who completed self-administered questionnaires, only 1,126 completed the section on self-reporting of hand hygiene practice. The median self-reported hand hygiene compliance was 80% (IQR 70-90%, range 0–100%), and was similar for most categories of HCW. Physicians had the lowest self-reported compliance with a median of 50%. (Figure 4.1 and Appendix C.6)

Current hand hygiene practices from direct observation

Intra-rater reliability between observers was assessed before collecting the data, and the agreement was at a level of 0.73, which can be interpreted as substantial.[170]

Out of a total of 3,564 recorded hand hygiene opportunities from 364 HCWs hand hygiene was observed in 475 (13.3%). Hand hygiene was considered to have been performed correctly in 318 (8.9%) opportunities and incorrectly in 157(4.4%). Amongst opportunities where hand hygiene was performed, the percentage of correct hand hygiene practice was 66.9% (318/475). The median hand hygiene compliance was 0% (IQR 0-8.01%, range 0–100%). The indication associated with the lowest compliance was “after touching patient surroundings” (38/3,564), while the highest compliance was “after body fluid exposure/risk” (610/3,564). HCWs, who did not use gloves during patient care (155/184), were more likely to perform hand hygiene correctly than HCWs who had been wearing gloves during patient care (59/113). The number of beds in the observation ward was negatively associated with compliance (Appendix C.9).
Figure 4.1: Score of current knowledge (n = 1,582) (top panel), % hand hygiene compliance by self-reporting (n = 1,126) (middle panel), and % hand hygiene compliance by direct observation (n = 364) (bottom panel) by explanatory variables.
Absence of hand hygiene was not found to be associated with any individual HCW characteristics. Hand hygiene practice using alcohol hand rub was much more likely to be performed correctly than hand hygiene using soap and water. Handrubing was more often performed correctly than handwashing (155/184 vs. 163/291). Male sex was associated with poorer adherence to recommended hand hygiene practices (Appendix C.7).

Of 364 HCWs for whom at least 1 (range 1-55) hand hygiene opportunity was observed, 248 (68.1%) were never observed to perform hand hygiene and only 116 (31.9%) performed hand hygiene at least once. The mean hand-hygiene compliance in HCWs was 8.9% (IQR 0-8.0%, range 0–100%).

Observations of hand hygiene practices are presented in Figure 4.1, Table 4.6, Appendix C.7, and Appendix C.8.

**Comparing hand hygiene practice between self-reporting and direct observation**

Hand hygiene compliance from self-reporting and direct observation showed a lack of consistency (Appendix C.6 and Appendix C.8). Self-reported compliance was nearly 10 times higher than the compliance from direct observation (Appendix C.8). Comparisons of current hand hygiene by direct observation and self-reporting are presented in Figure 4.1.
Table 4.6: Summary of hand hygiene performance for all opportunities requiring hand hygiene (n = 3,564)

<table>
<thead>
<tr>
<th>Hand hygiene practices</th>
<th>Not performed</th>
<th>Performed incorrectly</th>
<th>Performed correctly</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>3,089 (86.7 %)</td>
<td>157 (4.4 %)</td>
<td>318 (8.9 %)</td>
<td>3,564 (100 %)</td>
</tr>
</tbody>
</table>

**Time period**

<table>
<thead>
<tr>
<th>Time period</th>
<th>Not performed</th>
<th>Performed incorrectly</th>
<th>Performed correctly</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td>2,188 (87.6 %)</td>
<td>75 (4.4 %)</td>
<td>235 (9.4 %)</td>
<td>2,498 (100 %)</td>
</tr>
<tr>
<td>Afternoon</td>
<td>901 (84.5 %)</td>
<td>82 (4.4 %)</td>
<td>83 (7.8 %)</td>
<td>1,066 (100 %)</td>
</tr>
</tbody>
</table>

**Indication**

<table>
<thead>
<tr>
<th>Indication</th>
<th>Not performed</th>
<th>Performed incorrectly</th>
<th>Performed correctly</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before touching a patient</td>
<td>654 (91.7 %)</td>
<td>11 (1.5 %)</td>
<td>48 (6.7 %)</td>
<td>713 (100 %)</td>
</tr>
<tr>
<td>After touching a patient</td>
<td>656 (88.1 %)</td>
<td>18 (2.4 %)</td>
<td>71 (9.5 %)</td>
<td>745 (100 %)</td>
</tr>
<tr>
<td>Before clean/aseptic procedures</td>
<td>449 (84.6 %)</td>
<td>20 (3.8 %)</td>
<td>62 (11.7 %)</td>
<td>531 (100 %)</td>
</tr>
<tr>
<td>After body fluid exposure/risk</td>
<td>426 (69.8 %)</td>
<td>85 (13.9 %)</td>
<td>99 (16.2 %)</td>
<td>610 (100 %)</td>
</tr>
<tr>
<td>After touching patient surroundings</td>
<td>904 (93.7 %)</td>
<td>23 (2.4 %)</td>
<td>38 (3.9 %)</td>
<td>965 (100 %)</td>
</tr>
</tbody>
</table>

**Number of total beds**

<table>
<thead>
<tr>
<th>Number of total beds</th>
<th>Not performed</th>
<th>Performed incorrectly</th>
<th>Performed correctly</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 beds</td>
<td>930 (80.5 %)</td>
<td>67 (5.8 %)</td>
<td>158 (13.7 %)</td>
<td>1,155 (100 %)</td>
</tr>
<tr>
<td>14 beds</td>
<td>155 (86.6 %)</td>
<td>13 (7.3 %)</td>
<td>11 (6.2 %)</td>
<td>179 (100 %)</td>
</tr>
<tr>
<td>30 beds</td>
<td>1,266 (89.0 %)</td>
<td>52 (3.7 %)</td>
<td>104 (7.3 %)</td>
<td>1,422 (100 %)</td>
</tr>
</tbody>
</table>
4.3.4 Perceived barriers for non-compliance with hand hygiene

Possible barriers for non-compliance identified in an open question on the questionnaire are reported in Table 4.7. HCWs reported irritation on hands after performing hand hygiene (25.7%), and some respondents suggested adding some ingredients in the hand hygiene product to reduce the irritation. This issue was also expressed in the focus group discussions. Another theme from these discussions was that lowered hand hygiene performance could arise due to allergies to alcohol in some HCW. The view was expressed that the hospital should provide other products for hand hygiene considering the allergic factors. Lack of hand washing supplies (24.8%) and emergencies in the workplace (17.3%) were cited as the most important barriers were reported.

Table 4.7: Perceived barriers for non-compliance with hand hygiene reported by respondents (N = 1,582)

<table>
<thead>
<tr>
<th>Barriers</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irritation on hands after performing hand hygiene</td>
<td>460 (25.7)</td>
</tr>
<tr>
<td>Lack of hand washing supplies such as towel, soap, alcohol handrub including irregular water supply</td>
<td>393 (24.8%)</td>
</tr>
<tr>
<td>Emergency in workplace</td>
<td>273 (17.3%)</td>
</tr>
<tr>
<td>No facility for hand washing such as sink</td>
<td>261 (16.5%)</td>
</tr>
<tr>
<td>Lack of time (overburdened by work) or staff shortages</td>
<td>230 (14.5%)</td>
</tr>
<tr>
<td>Dislike the hand washing supplies such as alcohol hand rub (locally made), soap</td>
<td>173 (10.9%)</td>
</tr>
<tr>
<td>Misunderstanding on glove use</td>
<td>64 (4.1%)</td>
</tr>
<tr>
<td>Lack of administrative sanction of non-compliers or rewarding of compliers to perform hand hygiene</td>
<td>29 (1.8%)</td>
</tr>
<tr>
<td>Lack of scientific knowledge regarding impact of hand hygiene on hospital-acquired infection</td>
<td>25 (1.6%)</td>
</tr>
<tr>
<td>Lack of role model from colleagues or superiors</td>
<td>16 (1.0%)</td>
</tr>
</tbody>
</table>
4.3.5 Current beliefs about hand hygiene behaviour

This section summarizes the findings concerning beliefs about hand hygiene behaviour (derived from the opinion survey of the questionnaire on = 1,582). The questions regarding personal beliefs about hand hygiene following the TDF covered the following 12 domains: knowledge; skills; social/professional role and identity; beliefs about consequences; beliefs about capability; intentions; goals; memory, attention, and decision processes; environmental context and resources; social influences; emotion; and behavioural regulation. Optimism and reinforcement domains were excluded because in a systematic review of hand hygiene using a theoretical behavioural approach information was not reported on these two domains.\(^{[100]}\)

The internal consistency measures (Cronbach’s α) ranged between 0.64 - 0.69: knowledge = 0.69; skills = 0.65; social/professional role and identity = 0.68; beliefs about consequences = 0.64; intentions = 0.66; goals = 0.65; memory, attention, and decision processes = 0.65; environmental context and resources = 0.66; social influences = 0.64; emotion = 0.64; and behavioural regulation = 0.64.

The mean scores of each theoretical domain ranged from 2.58 to 4.86: knowledge = 4.14; skills = 3.67; social/professional role and identity = 2.58; beliefs about consequences = 4.66; beliefs about consequences = 4.46; intentions = 4.86; goals = 4.74; memory, attention, and decision processes = 4.55; environmental context and resources = 4.75; social influences = 3.81; emotion = 4.27; and behavioural regulation = 3.83. (Appendix C.9).

Reflecting the beliefs about hand hygiene behaviour, the “intentions” domain was reported to be the highest among all HCWs (4.86; 95% confidence interval [CI] 4.84 to 4.88), while the “social/professional role and identity” domain was reported to be the lowest among all HCWs (2.58; 95% CI 2.55 to 2.63).
4.3.6 Summary of relevant domain findings by applying the TDF

The relevant domain findings were summarized from qualitative data (from focus group discussion and semi-structured interviews) and quantitative data (questionnaires and direct observations). The results of this are presented in two parts: i) summarizing results by relevant theoretical domains, and ii) summarizing interrelations between the relevant domains.

Relevant theoretical domains

The fourteen domains of TDF identified from the two data sources as relevant to HCW hand hygiene compliance included: (1) knowledge; (2) skills; (3) social/professional role and identity; (4) beliefs about capabilities; (5) optimism; (6) beliefs about consequences; (7) reinforcement; (8) intentions; (9) goals; (10) memory, attention and decision processes; (11) environmental context and resources; (12) social influences; (13) emotion; and (14) behavioural regulation. Examples of specific beliefs from semi-structured interviews and focus group discussions are presented in Table 4.8.
Table 4.8: Examples of specific beliefs elicited from semi-structured interviews with key informants (n=5) and focus group discussions with representative of each type of healthcare worker (n=32)

<table>
<thead>
<tr>
<th>Domain/ Construct</th>
<th>Specific beliefs</th>
<th>Example quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Knowledge of condition</td>
<td>I believe that nurse aides and ancillary staff still did not know the link between improving hand hygiene practices and the impact of hospital-acquired infection. Nurse aides do not understand how to interpret current presentation of hospital-acquired infections on the ward.</td>
<td>“… nurse aides and ancillary staff, they still did not know the impact of hospital-acquired infection.... In monthly reports we routinely report about the case of hospital-acquired infection and impact of improving hand hygiene practices.... They did not understand this point yet....”</td>
</tr>
<tr>
<td>-Procedural knowledge</td>
<td>I do not know which hand hygiene product should be used in each activity and how different to use each product. We normally use the products that we have, I quite to use plain soap....”</td>
<td>“… current presentation of HAI, it is difficult to understand for nurse aides group... just show the graph in different color but they did not understand how to interpret it”</td>
</tr>
<tr>
<td>-Knowledge of task</td>
<td>I am aware of hand hygiene practices before and after touching patient, because it helps to prevent cross-transmission of pathogens between people and it helps to protect us from getting pathogens ourselves....”</td>
<td>“… before and after touching we should wash our hands.... We wash because it helps to prevent cross-transmission of pathogens between people and it helps to protect us from getting pathogens ourselves....”</td>
</tr>
</tbody>
</table>
Table 4.8: Examples of specific beliefs elicited from semi-structured interviews with key informants (n=5) and focus group discussions with representative of each type of healthcare worker (n=32) (cont.)

<table>
<thead>
<tr>
<th>Domain/ Construct</th>
<th>Specific beliefs</th>
<th>Example quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Skills</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Skills development</td>
<td>Posters give correct steps of hand hygiene practice. We perform correctly hand hygiene practice by looking at posters every time</td>
<td>“... (Posters) shows us how correct steps of hand washing. It helps in the memory, if we see it every time of hand washing. Then we do following these steps every time, we will do correctly in all steps.”</td>
</tr>
<tr>
<td>-Competence</td>
<td>I did not know how it is properly clean when I perform hand hygiene practice</td>
<td>“...How do we (nurse aides) know it’s properly cleaned...”</td>
</tr>
<tr>
<td>-Practice</td>
<td>I believe that workers will miss steps of hand hygiene practices because they think they have little physical contact with patients.</td>
<td>“... from our (ICWNs) observation, for several type of workers, such as auxiliaries, they have few activities that involve directly touching patients. They quite often touch the environment surrounding the patient.... then they will miss steps of hand hygiene practices”</td>
</tr>
<tr>
<td>-Skill assessment</td>
<td>I believe that proper hand hygiene is difficult to measure ICWNs try to immediately feedback to ward staff when they face the incorrect practice of hand hygiene and give teaching for proper hand hygiene practice</td>
<td>“... in this issue (correct of hand hygiene practice), it is difficult to measure....” “... really we (ICWNs) try to immediately tell them (other staff) that you do it is wrong practice, then we will teach what correct practice for hand hygiene is. You should do again following all steps of hand hygiene practices....”</td>
</tr>
</tbody>
</table>
Table 4.8: Examples of specific beliefs elicited from semi-structured interviews with key informants (n=5) and focus group discussions with representative of each type of healthcare worker (n=32) (cont.)

<table>
<thead>
<tr>
<th>Domain/ Construct</th>
<th>Specific beliefs</th>
<th>Example quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Skills</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Skill assessment</td>
<td>I believe that quality of hand hygiene practice of individual HCW is difficult to measure. They just wash their hands until feeling clean.</td>
<td>“….for the quality of hand hygiene practice of individual HCW (lough)….it is difficult to measure.... they just wash hands, they feel clean enough”</td>
</tr>
<tr>
<td><strong>Social/ professional role and identity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Professional identity</td>
<td>ICWNs try to immediately provide feedback when improper hand hygiene practice is occurring.</td>
<td>“….really we (ICWNs) try to immediately tell them (other staff) that what you do is wrong practice, then we will teach what correct practice for hand hygiene is. You should do it again following all steps of hand hygiene practices....”</td>
</tr>
<tr>
<td>- Professional role</td>
<td>All HCWs know when they should perform hand hygiene but they did not perform hand hygiene 100% of the time. Even nurses did not perform hand hygiene practice every time before doing aseptic procedures.</td>
<td>“…. they (all HCWs) know, they should wash their hands. But it is not 100 % to perform hand hygiene in practice, even nurses they must wash their hand when they will do aseptic procedure....”</td>
</tr>
</tbody>
</table>
Table 4.8: Examples of specific beliefs elicited from semi-structured interviews with key informants (n=5) and focus group discussions with representative of each type of healthcare worker (n=32) (cont.)

<table>
<thead>
<tr>
<th>Domain/ Construct</th>
<th>Specific beliefs</th>
<th>Example quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social/ professional role and identity</td>
<td>-Professional role: Hand hygiene is a standard part of my patient consultations</td>
<td>“Every month, ICWN will report information about HAI and make discussion with all ward staff to solve the problem.”</td>
</tr>
<tr>
<td></td>
<td>-Professional boundaries: Hand hygiene is not specific to just my specialty. Hand hygiene should be performed by everyone</td>
<td>“Information about HCAI, such as name of pathogen, cost of treatment, is presented monthly at our ward meeting, and it has resulted in improving behaviour of HCWs for a few days after meeting then they do the same practice. After notifying this issue, we will get more co-operative behaviour from a group of registered nurse than from a group of nurse aides…. because they did not understand how it involve them…. “</td>
</tr>
<tr>
<td></td>
<td>-Organizational commitment: ICWN should routinely assess knowledge of all HCWs</td>
<td>“….we have ICWN in every ward, if the hospital has enough budget to support, in every year we should routinely test knowledge of ward staff then we will get baseline results …. We should test again 3 months later for monitoring the changing trend….”</td>
</tr>
<tr>
<td>Beliefs about capabilities</td>
<td>-Self-confidence: I am confident that nurses do hand hygiene quite often after caring the patient</td>
<td>“…. In general, for nurses… especially nurses who have activity to directly contact patient such as touching a patient, taking bed bath…. They will do more cleanly for hand washing…”</td>
</tr>
</tbody>
</table>
**Table 4.8:** Examples of specific beliefs elicited from semi-structured interviews with key informants (n=5) and focus group discussions with representative of each type of healthcare worker (n=32) (cont.)

<table>
<thead>
<tr>
<th>Domain/ Construct</th>
<th>Specific beliefs</th>
<th>Example quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beliefs about capabilities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Perceived competence</td>
<td>Some HCW groups have inferior hand hygiene performance than other groups</td>
<td>“...under my observation, several type of HCWs performed hand washing...but hand washing is done less in group of hospital support staff, because they have less activities that require contact with the patient... they occasionally perform hand washing as normal habit, and they do not know the corrected steps of hand washing... they do not look at the poster as well...”</td>
</tr>
<tr>
<td>- Beliefs</td>
<td>I believe that actual hand hygiene practice is only hand washing with antiseptic soap</td>
<td>“...Actual hand hygiene practice is only hand washing with antiseptic soap...”</td>
</tr>
<tr>
<td></td>
<td>Alcohol-based handrub was preferable for using when HCWS do not feel their hands are dirty</td>
<td>“...but most HCWs will use alcohol-based handrub... And if they feel it is not dirty then they will not wash their hands...”</td>
</tr>
<tr>
<td>- Empowerment</td>
<td>Belief that without visual reminders (e.g. posters) HCWs may not remember to perform the correct steps of hand hygiene</td>
<td>“...these posters were placed at almost all sinks... it is helpful for following steps of hand washing...”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“... it is easily to guide the patients...we recommended patients to do hand washing following the steps that show this as well...”</td>
</tr>
<tr>
<td>Domain/ Construct</td>
<td>Specific beliefs</td>
<td>Example quotation</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------</td>
<td>------------------</td>
</tr>
<tr>
<td><strong>Optimism</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Optimism</td>
<td>Only proper hand hygiene can effectively prevent HCAI</td>
<td>“….hand washing must be performed at the correct time and with the correct steps for effective HAI prevention ....”</td>
</tr>
<tr>
<td>- Pessimism</td>
<td>Overall hand hygiene compliance is 70 % but incomplete adherence to hand hygiene guidelines in the steps performed</td>
<td>“Overall HCW’s hand hygiene is certainly 70 percent compliance that it is correct.... but all steps of hand washing maybe not completely followed.”</td>
</tr>
<tr>
<td>- Identity</td>
<td>Hand hygiene is performed well, if only for self-protection</td>
<td>“....they certainly performed proper hand washing before going back home for protecting themselves.... but during working shift, I am not sure....”</td>
</tr>
<tr>
<td></td>
<td>Gloves can replace hand hygiene practice because it takes too long to wash hands</td>
<td>“....when I am waiting long queue to wash my hand, I will use glove, because after discarding glove there is no need to wash hands, then I can continue to take care of another patients.”</td>
</tr>
<tr>
<td><strong>Beliefs about consequences</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Beliefs</td>
<td>Quality of hand hygiene is difficult to tell, while overall compliance of our ward is a round 70 %</td>
<td>“.... Overall compliance of our ward is around 70 percent. And for quality of hand washing, it is difficult to measure.... they just wash their hands, and they say it is clean enough ....”</td>
</tr>
<tr>
<td>- Outcome</td>
<td>Proper hand hygiene is effective at protecting HCWs and patients from infections</td>
<td>“....must be washed in proper hand hygiene practice, then it will be effective to protect themselves and patients. .... but in general they do not wash”</td>
</tr>
</tbody>
</table>
### Table 4.8: Examples of specific beliefs elicited from semi-structured interviews with key informants (n=5) and focus group discussions with representative of each type of healthcare worker (n=32) (cont.)

<table>
<thead>
<tr>
<th>Domain/ Construct</th>
<th>Specific beliefs</th>
<th>Example quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beliefs about consequences</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Characteristics of outcome</td>
<td>I believe that I will not wash my hands when they feel less dirty</td>
<td>“If my hand is less dirty then I will not wash my hands”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Anticipated regret</td>
<td>I believe that overall hand hygiene compliance of staff is more than 80%, but they perform incorrectly.</td>
<td>“...as I evaluate it, I think, overall compliance of our staff is okay, it is over more than 80 percent.... in general, they wash not completely all steps of recommendation.”</td>
</tr>
<tr>
<td></td>
<td>If the goal of making hand hygiene part of routine habit could be attained, then hand hygiene would be performed automatically</td>
<td>“If they make hand hygiene practice as normal habit, then they will do automatically.”</td>
</tr>
<tr>
<td><strong>Reinforcement</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Rewards</td>
<td>Rewards for good ICT work have been provided in the past but not in the most recent years</td>
<td>“...in last several years we have had infection control meetings annually, and rewards for good infection control team work were provided, but the meeting was skipped in later year”</td>
</tr>
</tbody>
</table>
Table 4.8: Examples of specific beliefs elicited from semi-structured interviews with key informants (n=5) and focus group discussions with representative of each type of healthcare worker (n=32) (cont.)

<table>
<thead>
<tr>
<th>Domain/Construct</th>
<th>Specific beliefs</th>
<th>Example quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforcement</td>
<td>Hand hygiene compliance could be improved by setting a competition in the hospital ward and providing the reward. Because staff of each ward love their own ward as home, they don’t want to have a bad image for their ward</td>
<td>“We should set a competition on hand hygiene between the wards in our hospital and also provide the reward. Because staff of each ward love their own ward as home, they don’t want to have a bad image for their ward”</td>
</tr>
<tr>
<td>Intentions</td>
<td>Intention to completely perform all hand hygiene steps was lacking because of the time this would consume</td>
<td>“...no, we quite do not complete all steps of hand hygiene practice because it take so long time to do until complete all steps (laughs)....”</td>
</tr>
<tr>
<td>Stages of change</td>
<td>They intend to wash their hands after taking care of the patient with a bed bath</td>
<td>“...every time, they will play attention to wash their hands after taking bed bath for patient....”</td>
</tr>
<tr>
<td>Goals</td>
<td>Hand hygiene knowledge and training are a necessity. “New intern students must be taught how to perform hand hygiene until correctly performing, before starting the activity of nursing.” “New staff must have basic knowledge about hand hygiene recommendation, and they must perform correctly.”</td>
<td>“New intern students must be taught how to perform hand hygiene until correctly performing, before starting the activity of nursing.” “New staff must have basic knowledge about hand hygiene recommendation, and they must perform correctly.”</td>
</tr>
</tbody>
</table>
Table 4.8: Examples of specific beliefs elicited from semi-structured interviews with key informants (n=5) and focus group discussions with representative of each type of healthcare worker (n=32) (cont.)

<table>
<thead>
<tr>
<th>Domain/ Construct</th>
<th>Specific beliefs</th>
<th>Example quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>When taking all priorities into considerations, hand hygiene is first priority</td>
<td>“... firstly for new staff, we will teach hand hygiene practice, until they do correctly all steps of hand washing....”</td>
</tr>
<tr>
<td></td>
<td>If the goal of making hand hygiene part of routine habit could be attained, then</td>
<td>“If they make hand hygiene practice as normal habit, then they will do automatically.”</td>
</tr>
<tr>
<td></td>
<td>hand hygiene would be performed automatically</td>
<td></td>
</tr>
<tr>
<td><strong>Memory, attention and decision processes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reminders are useful for my hand hygiene practice</td>
<td>“... it (poster) is helpful. It presents the hand washing steps, if we look at this every day. It will make memory....”</td>
<td></td>
</tr>
<tr>
<td>Not practicing hand hygiene is a conscious decision and decisions not to wash hands may result from a lack of awareness about benefits and the fact that it is perceived to be impractical</td>
<td>“... a lot of people, they know, when they should wash their hands, but they did not wash because they are less aware.... hand hygiene is not important, hand hygiene is not useful, it is impractical.... benefits of hand hygiene are beyond themselves....”</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.8: Examples of specific beliefs elicited from semi-structured interviews with key informants (n=5) and focus group discussions with representative of each type of healthcare worker (n=32) (cont.)

<table>
<thead>
<tr>
<th>Domain/ Construct</th>
<th>Specific beliefs</th>
<th>Example quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Memory, attention and decision processes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AHR was used instead of handwashing because it was quicker</td>
<td>“... When we need to quickly clean hands, the AHR was used instead before nursing care.”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>“...if we are working in rushed period when we have less time to spend in hand hygiene practice we will apply alcohol-based handrub....”</td>
<td></td>
</tr>
<tr>
<td>An easily visible hand hygiene station makes it easier to remember to practice hand hygiene. AHR is perceived to be a second choice option.</td>
<td>“... when they look at towel shelf, they saw, it has no towel supply.... in several people, they will use AHR instead....”</td>
<td></td>
</tr>
<tr>
<td><strong>Environmental context and resources</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>When I am busy, I am less likely to comply with hand hygiene guidelines</td>
<td>“... during day shift, it is so busy....it is difficult to do this, but I try to do as I can ....”</td>
<td></td>
</tr>
<tr>
<td>Easy access to hand hygiene stations makes it easier to practice hand hygiene.</td>
<td>“... Another factor is lack of towels to use....”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>“...especially during shift turning between night and day shift, towels are required more to use.... but it is difficult to manage to proper supply....”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>“The problem is.... there are not enough towels....”</td>
<td></td>
</tr>
</tbody>
</table>
### Table 4.8: Examples of specific beliefs elicited from semi-structured interviews with key informants (n=5) and focus group discussions with representative of each type of healthcare worker (n=32) (cont.)

<table>
<thead>
<tr>
<th>Domain/ Construct</th>
<th>Specific beliefs</th>
<th>Example quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environmental context and resources</strong></td>
<td>Availability of towels where they are needed may limit ability to perform hand hygiene.</td>
<td>“... when they look at the towel shelf, they saw, it has no towel supply, then they will not do completely all steps of hand washing.... they feel, it no needs to be done completely....”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“We support all resources for hand washing, I am confident we have enough supplies. But they fail to manage accountability in some wards”</td>
</tr>
<tr>
<td><strong>Social influences</strong></td>
<td>Other team members influence my hand hygiene practice</td>
<td>“...every time when hospital has a campaign to improve hospital quality, they will improve hand hygiene practice as well....”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“They will do well, if it is on period of promoting hand hygiene.”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“Every month, ICWN will report information about HCAI and make discussions with all ward staff to solve the problem.”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“If you can improve hand hygiene in doctors, then we will wash as well”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“when ICT come to the ward we will do more or might have less activity so have less required hand hygiene”</td>
</tr>
</tbody>
</table>
Table 4.8: Examples of specific beliefs elicited from semi-structured interviews with key informants (n=5) and focus group discussions with representative of each type of healthcare worker (n=32) (cont.)

<table>
<thead>
<tr>
<th>Domain/ Construct</th>
<th>Specific beliefs</th>
<th>Example quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social influences</td>
<td>Other team members influence my hand hygiene practice</td>
<td>“ICWN of the ward regularly feedback on hand hygiene to ward staff, but some staff were ignore because they found incorrect practice from ICWNs as well.”</td>
</tr>
<tr>
<td>Emotion</td>
<td>More concerned with hand hygiene practice because of fear to carriage pathogens back to home</td>
<td>“….they will fear to get pathogens from touching the patient and bring pathogens to their family so that every staff will concentrate more to clean their hands before going back home....”</td>
</tr>
<tr>
<td></td>
<td>Due to lack of towel at sink, I feel lazy to perform hand hygiene</td>
<td>“If I wash without towel, I could not wash. I fell lazy for waiting long queue, but it has no towel to use....”</td>
</tr>
<tr>
<td>Behaviour regulation</td>
<td>Hand hygiene practice of staff was monitored periodically by the ICWN</td>
<td>“Hand hygiene practice of our ward staff was evaluated periodically by ICWN.” “….It’s going to have an evaluation form, it was evaluated periodically (hand hygiene practice)....” “….under my observation....hand washing is done less in group of hospital support staff, because they have less activity to contact the patient.... if they occasionally perform hand washing as normal habit, and they did not know the corrected steps of hand washing.... they did not look at the poster as well...then I will said loudly,....Um.... please wash your hands in the correct steps ”</td>
</tr>
</tbody>
</table>
**TDF 1: Knowledge**

The knowledge domain considered knowledge of condition/scientific rationale, procedural knowledge, and knowledge of task environment.

From the questionnaire to assess the level of knowledge about hand hygiene similar results were found for different types of HCWs and different departments (Figure 4.1), while the questionnaire survey indicated high agreement that the “knowledge” domain \( (4.41, 95\% \text{ CI } 4.09 \text{ to } 4.18) \) had an impact on hand hygiene behaviour. Selecting an improper product for hand hygiene was commonly seen in the observations and may reflect lack of knowledge.

In the focus group of ICWNs, lack of knowledge about scientific rationale for hand hygiene was found in a group of auxiliaries. While, in the focus group of nurse aides, participants said that they knew why they should wash their hands (i.e. because proper hand hygiene helped to eliminate cross-transmission between HCW and patient), but they did not know what criteria to use for selecting appropriate hand hygiene products.

In all of the focus groups, almost all HCWs claimed to have enough procedural knowledge, knowing when they should wash their hands and how many steps there were in correct hand hygiene practice. But a common theme was that not all steps of hand hygiene practice were followed. In some cases, this may have been because of emotional factors (i.e. if having a feeling of “not dirty” after touching a patient, then the HCW would be likely to not perform hand hygiene or perform incomplete steps of hand hygiene. Conversely, if having a feeling of “dirty” after performing an aseptic procedure, then an HCW would be more likely to concentrate to perform hand hygiene practices). Focus group participants expressed the view that aseptic procedure for treatment was strongly related to performance of hand hygiene practice in nurse groups, and touching the environment of patient was weakly related to hand hygiene practices in groups of auxiliaries.
From the semi-structured interviews, most key administrators expressed confidence that all HCWs had proper knowledge about hand hygiene guidelines, but believed that they often ignored hand hygiene in practice. Only one key administrator mentioned that knowledge of hand hygiene amongst HCWs needed to improve. While similar results were found in focus groups of ICWNs, this group suggested that improving knowledge in hand hygiene practice of HCWs by setting routine knowledge assessments for all HCWs.

Almost all HCWs have enough knowledge of a condition to clean their hands but they did not do every time as required, because emotional concepts of “dirtiness” and “cleanliness” of each nursing activity were used as criteria to perform hand hygiene. When finishing activities involving the patient, however, it does matter that activity was high or low risk activity. If HCW have this feeling of dirtiness, then they will perform hand hygiene, and if they feel this cleanliness, then they will not perform hand hygiene.

**TDF 2: Skills**

The skills domain includes skills, skills development, competence, ability, interpersonal skills, practice, and skill assessment.

From the questionnaire, there was moderately high agreement that the “skills” domain (3.67, 95% CI 3.62 to 3.73) had an impact on hand hygiene behaviour, while hand hygiene observations showed hand hygiene was often performed with incomplete steps and this could be considered as indicating lack of skills.

In the focus group discussion, lack of skills to assess proper hand hygiene was found in a group of nurse aides. Similar results were found from a group of ICWNs. ICWNs try to give feedback immediately to staff when wrong hand hygiene practice is found.
In the semi-structured interviews, the need to improve skills was raised. The view was expressed that while all staff perform hand hygiene, many perform it incorrectly. Staff also expressed a belief that proper hand hygiene is difficult to measure.

**TDF 3: Social/ professional role and identity**

The domain of social/ professional role and identity covered professional identity, professional role, social identity, identity, professional boundaries, professional confidence, group identity, leadership, and organizational commitment.

From the questionnaire, there was moderately low agreement that the “skills” domain (2.58, 95% CI 2.52 to 2.63) had an impact on hand hygiene behaviour. It was also suggested that HCWs might try to do less activity with the patients when the ICT were performing hand hygiene observations because of concerns about the feedback the ICT would provide.

The focus group discussions generally revealed high professional confidence from all HCWs but less confidence in hand hygiene practices. This was because those joining the discussions did not feel sure about the quality and consistency of hand hygiene practice among HCWs, due to several reasons including individual (knowledge, forgetfulness, awareness) and social contexts (less supplies, staffing, high workload, urgent work).

The role of ICWNs was thought to be clearly identified and the ICWN was expected to be a key player to promote hand hygiene in each ward. Difficulties to act in the role of ICWN were also mentioned, because ICWNs attempted to perform their roles but did not always have sufficient co-operation from other staff.

**TDF 4: Beliefs about capabilities**

The beliefs about capabilities domain covered self-confidence, perceived competence, self-efficacy, perceived behavioural control, beliefs, self-esteem, empowerment, and professional confidence.
From the questionnaire, there was high agreement that the “beliefs about capabilities” domain (4.66, 95% CI 4.63 to 4.69) had an impact on hand hygiene behaviour. However, evidence of misunderstanding about hand hygiene practice was found in the focus group, where the belief was expressed that hand hygiene practice are only hand washing with water and soap.

Perceived behavioural control was reported, and the view was expressed that HCWs were likely to perform hand hygiene with more concentration, when caring for a patient in a dirty activity. This was found in almost all the group discussions. Some groups of HCWs also showed less confidence in their ability to perform hand hygiene practice.

Some interviewees expressed doubts about the capabilities of hand hygiene to reduce HCAI, pointing to a lack of evidence in their hospital setting. It was suggested that other aspects of infection control programme might be more effective to reduce HCAI than improving hand hygiene. Some interviewees mentioned the quality of water and towels as limiting their capabilities, and stated that the quality of water and towels needed to be assured before improving hand hygiene.

**TDF 5: Optimism**

The optimism domain included optimism, pessimism, unrealistic optimism, and identity.

Optimism was expressed in both the focus groups and the interviews that proper hand hygiene by HCWs could prevent HCAIs. There was pessimism that the hand hygiene compliance could be increased to 100 %, because of perceived difficulties in promoting hand hygiene in the hospital.

**TDF 6: Beliefs about consequences**

The “beliefs about consequences” domain covered beliefs, outcome expectancies, characteristics of outcome expectancies (physical, social, emotional), anticipated regret, and consequents.

From the questionnaire, there was high agreement that “beliefs about consequences” domain (4.46, 95% CI 4.41 to 4.51) had an impact on hand hygiene behaviour. A common outcome expectancy
that was found in both the interview and the focus group discussions was that hand hygiene can effectively protect HCWs and patients from infections. Beliefs were also expressed that hand hygiene could result from a feeling of dirty hands.

**TDF 7: Reinforcement**

The reinforcement domain covered rewards (proximal/distal, valued/not valued, probable/improbable) incentives, punishment, consequents, reinforcement, contingencies, and sanctions.

Rewards from competition were proposed as a potential reinforcement to promote hand hygiene from the focus group. This domain was, however, relatively poorly addressed from both the interviews and the focus groups.

**TDF 8: Intentions**

The domain “Intentions” covered stability of intentions, stages of change model, and transtheoretical model and stages of change.

From the questionnaire, there was high agreement that the “intentions” domain (4.86, 95% CI 4.84 to 4.88) had an impact on hand hygiene behaviour, but lack of stability of intentions to complete all steps of hand hygiene was found in all groups of focus group discussion and it was suggested that this might be a result of time pressure.

**TDF 9: Goals**

The “goals” domain covered goals (distal/proximal), goal priority, goal/target setting, goals (autonomous/controlled), action planning, and implementation intention.

From the questionnaire, there was high agreement that the “goals” domain (4.74, 95% CI 4.71 to 4.76) had an impact on hand hygiene behaviour, while goal priority and goal/target setting were important themes in the semi-structured interview from key administrators, and in the focus group of
ICWNs. New staff or new students were considered to be high priority who must receive training on hand hygiene guidelines before starting work.

**TDF 10: Memory, attention and decision processes**

The “memory, attention and decision processes” domain covered memory, attention, attention control, decision making, and cognitive overload/tiredness.

From the questionnaire, there was high agreement that the “memory, attention and decision processes” domain (4.55, 95% CI 4.52 to 4.59) had an impact on hand hygiene behaviour, while the focus group of ICWNs and nurse aides suggested lack of awareness of correct hand hygiene practice had a negative impact on decision making.

Posters acted as important reminders and were an important determinant of attention control for hand hygiene behaviour of HCWs. Some HCWs stated that when HCW faced rushed periods of work alcohol handrub (AHR) was the preferable decision for hand hygiene practice (and no awareness of the better antibacterial performance of AHR compared to soap and water was demonstrated).

**TDF 11: Environmental context and resources**

The “environmental context and resources” domain covered environmental stressors, resources/material resources (availability and management), organization culture/climate, salient events/critical incidents, person x environmental interaction, and barriers and facilitators.

From the questionnaire, there was high agreement that the “environmental context and resources” domain (4.75, 95% CI 4.73 to 4.78) had an impact on hand hygiene behaviour. Similar findings were obtained from the focus group discussions.

Lack of resources for hand hygiene in the ward level were addressed in all focus groups as barriers for hand hygiene behaviour, but some interviewees said that proper supplies and resources were available, and they suggested that the reasons behind poor hand hygiene compliance in each ward
were more due to failure of resource management instead. A theme expressed by administrators was that quality of resources was questionable because re-useable towels were currently used in this hospital.

**TDF 12: Social influences**

The “social influences” domain covered social pressure, social norms (subjective, descriptive, injunctive norms), group conformity, social comparisons, group norms, social support (personal/professional/organizational, intra/interpersonal, society/community), power (hierarchy), intergroup conflict, alienation, group identity, and modelling.

From the questionnaire, there was moderately high agreement that the “social influences” domain (3.86, 95% CI 3.81 to 3.90) had an impact on hand hygiene behaviour.

In the focus group discussion, comparison of hand hygiene behaviour among groups of HCWs was reported, and some HCWs claimed that the reasons for their own non-compliance were the non-compliance of other staff as well. Social pressure such as hospital accreditation was thought to be effective in promoting hand hygiene hospital-wide. Physicians were widely considered as role models for hand hygiene behaviour.

**TDF 13: Emotion**

The “emotion” domain covered fear, anxiety, affect, stress, depression, positive/negative affect, and burn-out.

From the questionnaire, there was high agreement that the “emotion” domain (4.27, 95% CI 4.23 to 4.32) had an impact on hand hygiene behaviour. Fears of carriage of pathogens that can be transmitted to their family were addressed in the focus group, and the view was expressed that this could result in more concentration on hand hygiene by HCWs before going home.
**TDF 14: Behaviour regulation**

The “behaviour regulation” domain covered self-monitoring, habit-breaking, and action planning.

From the questionnaire, there was moderately high agreement that the “emotion” domain (3.83, 95% CI 3.78 to 3.88) had an impact on hand hygiene behaviour.

From the focus group of nurse aides, in each ward, hand hygiene amongst ward staff was periodically officially monitored by the ICWN. But unofficial monitoring was performed more frequently, and then verbal feedback was immediately provided by the ICWN and considered to contribute to breaking the habit of non-compliance with hand hygiene of the targeted HCW. Lack of knowledge on steps of hand hygiene was also addressed by this form of monitoring.

**Interrelations between the relevant domains**

By applying the TDF, this section summarises the domain findings by considering the interrelations of the relevant domains from the all relevant domain findings. This section consists of two parts: i) the interrelations of the relevant domains and current knowledge, ii) the interrelations of the relevant domains and current hand hygiene practice.

**The interrelations of the relevant domains and current knowledge**

For the 1,582 HCWs who completed the questionnaire survey, Pearson’s correlation coefficient was used assessing interrelations between survey answers. Interrelations between current knowledge and the relevant domains were considered as having a low association with values of $r$ ranging from -0.04 to 0.18. No correlation between the knowledge score about hand hygiene from the questionnaire assessment and the belief or “knowledge” domain was seen ($r = 0.01$). (Appendix C.10)

**The interrelations of the relevant domains and current hand hygiene practices**

Of 364 HCWs whose hand hygiene practices were directly observed, interrelations between the relevant domains and current hand hygiene behaviour were all found to have only low-level associations with $r$ ranging from -0.07 to 0.16. (Appendix C.11)
4.3.7 Mapping domain finding to the Behaviour Change Wheel’s COM-B system

This section links the domain finding to addresses the factors influencing the hand hygiene behaviour by using the COM-B system (Table 4.2) and the model for illustrating individual, team, and organizational levels. (Table 4.3)

Linking the domain findings to the COM-B system

Factor analysis was employed to relate the domain findings to the COM-B system with the aim of identifying factors likely to be important in changing behaviour. Factor analysis of twelve domains yielded a three-factor solution, with a combined explained variation of 100 % (Table 4.9). In considering the factors labels, we linked to the work of the Behaviour Change Wheel’s COM-B system, which conceptualized three factors necessary for behaviour to occur\(^\text{37}\) (Table 4.3).

The factors were thus labeled as follows: motivation (46.3% of variance, \(\alpha = 0.32\)), capability (34.5% of variance, \(\alpha = 0.00\)), and opportunity (19.2% of variance, \(\alpha = 0.22\)) (Table 4.7 and Figure 4.2).

Capability represented psychological and physical factors that consisted of four domains: knowledge; skills; memory, attention and decision processes; and behavioural regulation. The relevant domains were found to have a low to moderate relation to capability on hand hygiene behaviour, with \(r\) ranging from -0.06 to 0.54.

Opportunity, social and physical factors consisted of two domains: social influences, and environmental context and resources. The relevant domains showed a low to moderate relationship to opportunity for hand hygiene behaviour, with \(r\) ranging from 0.05 to 0.57.

Motivation represented reflective and automatic factors and consisted of six domains: social/professional role and identity; beliefs about capabilities; beliefs about consequences;
intentions; goals; and emotion. The relevant domains were moderately related to motivation on hand hygiene behaviour, with r ranging from -0.06 to 0.64.

Capability was negatively correlated with opportunity (r=-0.19, p<0.001). Capability was negatively correlated with motivation (r=-0.13, p<0.001). Motivation was negatively correlated with opportunity (r=-0.01, p=0.60).

**Table 4.9**: Rotated component matrix of theoretical domains and explained variance of each factor for all participants who completing the questionnaire (N = 1,582)

<table>
<thead>
<tr>
<th>DOMAINS</th>
<th>FACTORS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Motivation</td>
<td>Capability</td>
<td>Opportunity</td>
</tr>
<tr>
<td>Knowledge</td>
<td>0.28</td>
<td>-0.06</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Skills</td>
<td>0.07</td>
<td>0.54</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>Social/professional role and identity</td>
<td>-0.06</td>
<td>0.17</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>Beliefs about capabilities</td>
<td>0.62</td>
<td>0.13</td>
<td>-0.004</td>
<td></td>
</tr>
<tr>
<td>Beliefs about consequences</td>
<td>0.31</td>
<td>0.50</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>Intentions</td>
<td>0.57</td>
<td>0.20</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>Goals</td>
<td>0.64</td>
<td>0.18</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Memory, attention and decision processes</td>
<td>0.48</td>
<td>0.15</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Environmental context and resources</td>
<td>0.06</td>
<td>0.72</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Social influences</td>
<td>0.22</td>
<td>0.19</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td>Emotion</td>
<td>0.61</td>
<td>0.14</td>
<td>-0.06</td>
<td></td>
</tr>
<tr>
<td>Behavioural regulation</td>
<td>0.14</td>
<td>0.47</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td><strong>PERCENT OF VARIANCE</strong></td>
<td>46.3</td>
<td>34.5</td>
<td>19.2</td>
<td></td>
</tr>
</tbody>
</table>

Rotation method: Varimax with Kaiser normalisation
Figure 4.2: Factors and theoretical domains with Cronbach’s alpha (α) and domain loading (N = 1,694) Factor correlation (r) is provided with p values (two-tailed).
Linking the domain finding to the model for illustrating individual, team, and organizational levels

The level of the constructs in the theoretical domain was illustrated in individual, team, and organizational levels of hand hygiene behaviour based on construct allocations reported by Michie et al. [16]

*Individual level of hand hygiene behaviour*

Environmental stressors including high workload and understaffing were found in this study that affected hand hygiene behaviour of HCWs. Social pressure such as hospital accreditation was addressed in the focus group and was felt to have an impact on individual hand hygiene behaviour hospital-wide.

*Team level of hand hygiene behaviour*

Social comparison was proposed as a strategy to promote hand hygiene, and was addressed in the focus group discussion with the nurse aides. For example, it was suggested to have a competition on hand hygiene between the wards with each ward designing a strategy to promote hand hygiene on their own ward. The hospital administrator should support the incentives or awards for the winning wards.

*Organisational level of hand hygiene behaviour*

Resources/ material resources were mentioned and both their availability and their management were discussed. For the availability, lack of hand hygiene supplies were addressed in all sources of data, and the management of the resources was addressed in the interviews of key administrator that needed to improve the management of the resource in the ward level. The quality of resources such as water, towels, was also mentioned and the need for quality-assurance was considered.
4.4 Discussion

4.4.1 Key findings

This study represents one of the first reports applying a theoretical domain framework to identify systematically the barriers or enablers that may affect hand hygiene behaviour of HCWs in resource limited setting. The results showed clear differences across theoretical domains at the individual level, thus suggesting some explanations for implementation difficulties. Fourteen domains of TDF were identified as potential barriers/enablers to hand hygiene practice of HCWs. The domain findings of this study can be considered as determinants of behaviour change.

4.4.2 Comparing study results with other studies

These results are consistent with findings from a systematic review of hand hygiene improvement strategies using a behavioural approach in another setting.\textsuperscript{[100]} From this review, most studies used determinants at the individual and institutional level that corresponded to twelve domains having an impact on behaviour.\textsuperscript{[100]} The findings in this study also show consistency with the questionnaire survey on identifying barriers and levers for best hand hygiene practice of Dyson et al.\textsuperscript{[174]} From previous studies\textsuperscript{[98, 100, 174]} the domains of “optimism” and “reinforcement” are less frequently reported to influence hand hygiene behaviour amongst HCWs. Reinforcement using reward incentives has also been reported to have a high association with the successful promotion of hand hygiene in the review and network meta-analysis of the comparative efficacy of interventions to promote hand hygiene by Luangasanatip et al.\textsuperscript{[82]}

The current study aimed to address both barriers and enablers as determinants for different levels of behaviour. Because HCWs in the hospital usually work as teams the relations between HCWs and their impact on hand hygiene behaviour needs to be understood before designing the intervention. Strategies to improve hand hygiene could include focus at the individual level, involving consideration
of intrapersonal factors, and the consideration of the institutional level (such as ward level or hospital level, where the local context of each ward/hospital could be considered in the development of an intervention), which involves interpersonal and community factors. [21]

The studies by Fuller et al.[108] and Gould et al.[175] conducted interventions to promote hand hygiene by engaging the ward in the process of implementation. Consistent with findings of this study that correlation between social context and individual factors on hand hygiene behaviour are addressed in groups of hand hygiene observations (individual interactions within group: verbal reminding in the ward) and in the focus group, such as routine monitoring of ICWNs acting either as an official or unofficial monitor affected individual behaviour. These finding echo results from previous intervention studies on health behaviour that the domain social influence is considered relevant to successfully change behaviour.[176]

Knowledge of hand hygiene is frequently reported as one of the most important determinants that affect hand hygiene behaviour.[100, 177, 178] In this study, lack of knowledge of HCWs was strongly suggested in the focus groups and in the direct observations, and ignorance about the greater antibacterial properties of alcohol handrub compared with soap and water appeared to be widespread. Conversely, in the semi-structured interviews with key administrators and in the knowledge scores from self-administrated questionnaire the view was expressed that knowledge about hand hygiene was sufficient. All HCW beliefs on “knowledge” domain were also are reported as having a big effect on hand hygiene behaviour, but skepticism about the value of the hand hygiene to prevent HCAI was revealed by all methods. Self-reported hand hygiene behaviour is usually considered as over-reporting: this has been found in this study and in several previous studies as well.[179-181] In this study, self-reported hand hygiene compliance was found to be 10 times higher than that recorded by direct observation.
4.4.3 Theoretical implications

There are implications here for theories of behaviour change as applied to hand hygiene. We can more precisely define barriers and enablers on hand hygiene behaviour and their relevance for implementation of interventions in other resource-limited setting using this approach. This method may also be used to get a systematic understanding of other health professional behaviour in other resource-limited settings as well. It can help to identify target groups and whether changes in the domains are likely to directly influence implementation of intervention. The Behaviour change Technique (BCT) Taxonomy (v1) has been developed to standardize the reporting of intervention content, and identify their potentially ‘active ingredients’.\textsuperscript{182}

4.4.4 Practical implications

Intervention development should include identifying relevant domains as a key part of the process.\textsuperscript{94, 95} Recently health professional behaviour in a range of clinical areas has been investigated by using the TDF. Relevant domains were identified in the processes of intervention development.

In linking theoretical domains to BCTs, BCTs provide a guide for how to do this.\textsuperscript{183} Each technique may work best if it is designed for and adapted to the individual context. When designing interventions to improve hand hygiene, target domains should not only be selected but also the relevance of each domain to behaviour change should be considered as well.

Example of using the BCT Taxonomy\textsuperscript{176} to guide intervention development on the basis of TDF analyses are seen in antibiotic prescribing\textsuperscript{184} and hand hygiene.\textsuperscript{99, 185} Characterisation of implementation of interventions in terms of behaviour change techniques and theory has been reviewed by Steinmo et al.\textsuperscript{186} This has helped to illustrate the utility of the Behaviour Change Wheel (BCW), the BCT Taxonomy and the TDF, tools recognised for providing guidance for intervention design, and for characterising an existing intervention to implement evidence-based care.\textsuperscript{186}
4.4.5 Strengths, limitations and future directions

A key strength of this study is using triangulation to identify the factors associated with hand hygiene from different viewpoints. For example, comparing direct observation on hand hygiene with self-reporting of hand hygiene practice, and using qualitative and quantitative approaches. A second strength is applying a systematic approach to explore the factors affecting hand hygiene behaviour, which can be linked to behaviour change techniques in the intervention phase as well.

There are some limitations in this study. First, the allocation of certain items to domains was not always clear. Second, some domains might have overlapping meaning in study settings that can affect the study results such as the domain social/professional role and identity and the domain social influences. Third, a small number of questions for each domain may affect the reliability of the results. Excluding the domain optimism and reinforcement from the belief survey may have had some effect on the results of the factor analysis.

Future research is needed to evaluate how these domains relate to behaviours targeted in the promotion of hand hygiene, and how various interventions can change these behaviours.

4.5 Conclusions

This study has demonstrated a feasible method to identify the potential barriers/enablers to hand hygiene practice of HCWs using a TDF approach, highlighting factors that need to be addressed before designing interventions. Understanding hand hygiene behaviour among HCWs is important part of changing behaviour. The results are of potential use for designing interventions to promote hand hygiene.
Chapter 5

Impact of a multimodal hand hygiene improvement intervention

5.1 Introduction

Healthcare-associated infections (HCAIs) are a global problem and a major source of preventable morbidity and mortality worldwide, but particularly so in low and middle income countries (LMICs).\[4\] A recent review estimated the pooled prevalence of HCAI in developing countries (defined as Organization Economic Co-operation Development (OECD) low or middle income countries) to be 15.5 per 100 patients, and highlighted the need to improve infection control practices.\[4\] Rates of surgical site infection have been reported to range from 12 to 39% in developing countries compared to 2 to 5% in developed countries and rates of HCAI in neonates have been found to be 12 times higher in developing countries.\[5, 6\] Mortality due to such infections in developing countries is found to greatly exceed that in developed countries.\[7\]

There is, however, evidence from quasi experimental research that concerted and sometimes low-cost interventions are able to greatly reduce the hospital transmission and prevalence of multi-drug resistant organisms (MDROS),\[187\] resulting in improved patient outcomes.\[17\]

Improving hand hygiene practice among healthcare workers (HCW), in particular, is thought to substantially reduce the transmission of important healthcare-associated pathogens resulting in reduced incidence of healthcare-associated infection (HCAI).\[17, 79, 158, 188-190\] Such interventions are
relatively inexpensive and thought likely to be cost-effective (and potentially cost-saving as a result of reduced infections rates).[191]

However, a 2010 Cochrane review has highlighted the lack of methodologically sound research evaluating interventions to improve hand hygiene: only four studies met the minimum inclusion criteria and no study came from a lower- or middle-income country.[7] An increasing number of “high quality” studies on interventions for hand hygiene after 2009 have been reported in the latest systematic review in 2015; using the same criteria as in the previous review 41 studies met the inclusion criteria, and also 5 of these came from a lower- or middle-income country.[82]

Moreover, an earlier review identified a need for stronger study designs to link improved hand hygiene compliance with reductions in HCAIs (currently such evidence is based only on observational studies).[7] There are also very few evaluations of such intervention using strong study designs in lower and middle income countries (LMICs).[47, 82]

Previous data from our research setting has suggested hospital infection control guidelines may not have been implemented consistently due, in part, to resource constraints.[14] More recent qualitative research carried out at our hospital site into the causes of poor hand hygiene compliance identified several obstacles to improving appropriate hand hygiene behavior (see chapter 4).

Available evidence suggests that hand hygiene promotion (HHP) with the components of the WHO multimodal hand hygiene improvement strategy is an effective approach to improve HCW hand hygiene compliance.[47, 82] The World Health Organization (WHO) has developed evidence-based “WHO Guidelines on Hand Hygiene in Health Care” to support health-care facilities to improve hand hygiene and thus reduce HCAI.[89] The strategy described in these guidelines has been designed to be used by any health-care facility, irrespective of the level of resources or whether the facility has already implemented any hand hygiene initiatives.
This approach promoted by the WHO guidelines identifies five moments for hand hygiene (before patient contact, before aseptic procedure, after body fluid exposure, after touching a patient, after touching a patient’s surroundings). These guidelines aim to encourage good hand hygiene compliance in the real world and recommend a multimodal HHP strategy making use of five components: 1) system change (for example, changing systems to ensure that alcohol-based hand-rub (ABHR) is readily available wherever and whenever needed), 2) training and education, 3) observation and feedback, 4) reminders in the hospital, and 5) a hospital safety climate.

In conclusion, there is a need for methodologically rigorous research to evaluate the impact of a multimodal intervention based on the WHO recommendations. The need for such research is greatest in resource-constrained settings in lower and middle income countries where the burden of disease due to HCAIs is the greatest. Adapting WHO’s guidelines to local conditions is important and there is a need to generate action plans which are appropriate to their own setting.

The aim of this study was to evaluate the impact of a multimodal intervention to improve hand hygiene in HCWs on directly observed compliance with the WHO’s recommended five moments for hand hygiene in a LMIC setting using a using a cluster-randomized trial.

5.2 Methods

5.2.1 Participants and Setting

The study site was a 1000-bed hospital, which is located in the northeast of Thailand. This hospital provides facilities serving a medical school, residency training, tertiary care, and is a regional referral center for the northeast part of Thailand. For this study we recruited 58 wards including 20 intensive-care-unit wards (ICU wards) and 38 non-intensive-care-unit wards (non-ICU wards).
The total number of admission is around 70,000 per year. This hospital has a specialist infection control team (ICT) including four specialist infection control doctors (ICDs) (2 for children, and 2 for adults), four specialist infection control nurses (ICN), and one assistant. The role of this ICT is very multi-faceted, and involves planning, monitoring, evaluating, updating, and educating. Its function is to prevent and control nosocomial infections.

Our study setting also has an infection control committee (ICC). The ICC includes key administrators from all departments of the hospital. The role of the ICC is similar to the ICT at an administrative level. Each ward has at least one infection control ward nurse (ICWN), who has been specially trained on guidelines for infection control by the ICT and is the responsible person to lead and coordinate with ward staff and the ICT to prevent and control nosocomial infections in their own ward.

Participants were all HCWs, having direct patient contact in at least one of these 58 in-patient wards at the hospital site.

Eligibility Criteria

All HCWs with direct patient contact (physicians, nurses, aides, and ancillary staff) were included in the study. Visitors and hospital staff such as medical students, nursing students, physical therapists, and radiologists were also included. There were no exclusion criteria.

5.2.2 Ethics statements

Ethical permission for this study was obtained from the Ethical and Scientific Review Committees of Faculty of Tropical Medicine, Mahidol University, Thailand, and of hospital site (Appendix D.1). The study protocol and its associated documents were also approved.
5.2.3 Study design

The research design was a prospective stepped wedge trial using a ward as the study cluster. A stepped wedge design is a type of cluster randomized controlled trial which is appropriate when there are prior reasons to believe the intervention will be beneficial (as opposed to equipoise) and when it is impractical to deliver the intervention to all study units simultaneously. Both conditions hold here.\[105, 192\]

The time step in which the intervention was made in each ward was randomly selected using computer-generated sequences. All of the 58 in-patient wards at the hospital were randomly selected (using a computer generated sequence) to assign the order of applying the intervention at each time step.

5.2.4 Study Duration

The study duration was 74 weeks between 1\textsuperscript{st} December 2013 and 2\textsuperscript{nd} May 2015. The study was divided into 3 phases;

1) The pre-intervention period was planned as a 5-week baseline period and was actually conducted between 1\textsuperscript{st} December 2013 and 4\textsuperscript{th} January 2014 (a total of 5 weeks).

2) The intervention period was planned to last 58 weeks but was actually conducted between 5\textsuperscript{th} January 2014 and 28\textsuperscript{th} March 2015 and lasted a total of 64 weeks.

3) The post-intervention period was planned as a 5-week follow-up period, and was actually conducted between 29\textsuperscript{th} March and 2\textsuperscript{nd} May 2015 (a total of 5 weeks).
5.2.5 Study intervention

The WHO Multimodal Hand Hygiene Improvement Strategy\textsuperscript{[46]} was applied as the study intervention, making use of five components as described in section one (Table 5.1) with the aim of inducing behavioural change in relation to improved hand hygiene.

The intervention aimed to engage participating ward staff in the decision-making process of how to apply the WHO multimodal strategy to their ward. This engagement made use of a “Menu” provided to ward staff to help them design a customized intervention for their ward. The Menu contained four key elements. The first was the detail of each component of the WHO strategy with a number of suggestions for how this could be applied and a minimum requirement for implementing each component. The second was detail of the stepwise approach, which determined the intervention steps. The third contained detail of the WHO recommendations for implementation of each component of the WHO strategy. The last was the ward assessment that allowed the ward to consider all components of the strategy, and how each component could best be implemented in that particular ward and to provide the reasons why specific intervention components should or should not be applied (Appendix D.2).

The ward could freely decide to adapt the sequence of implementing the five components but they were asked to come up with a definite plan for implementing all components. A blank sheet for the original ideas of the ward to generate improvement strategy components that did not necessarily fit into WHO-defined five components was also provided under supervision of the ICT and research team.
A “Guide to the Implementation of the WHO Multimodal Hand Hygiene Improvement Strategy”[46] was translated in Thai as the intervention manual. This was made available to all wards in two forms: an electronic file and a hard copy.

**Table 5.1: Description of the key components of the intervention**

<table>
<thead>
<tr>
<th>The intervention components</th>
<th>Definition/Activity</th>
</tr>
</thead>
</table>
| System change a             | Ensuring that the necessary infrastructure/materials are in place to allow health-care workers to practice hand hygiene. This includes two essential elements:  
• access to a safe, continuous water supply as well as to soap and towels;  
• readily accessible alcohol-based handrub at the point of care. b |
| Training / Education a      | Providing regular training on the importance of hand hygiene, based on the “My 5 Moments for Hand Hygiene” approach, and the correct procedures for handrubbing and handwashing, to all health-care workers. |
| Evaluation and feedback a   | Monitoring hand hygiene practices and infrastructure, along with related perceptions and knowledge among health-care workers, while providing performance and results feedback to staff. |
| Reminders in the workplace a| Prompting and reminding health-care workers about the importance of hand hygiene and about the appropriate indications and procedures for performing it. |

a Adapted from the WHO multimodal hand hygiene improvement strategy (http://www.who.int/gpsc/5may/Guide_to_Implementation.pdf) [46]

b Point of care – The place where the patient, the health-care worker, and care or treatment involving contact with the patient or his/her surroundings occurs.
Table 5.1: Description of the key components of the strategy on the intervention (cont.)

<table>
<thead>
<tr>
<th>The intervention components</th>
<th>Definition/Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional safety climate(^a)</td>
<td>Creating an environment and the perceptions that facilitate awareness-raising about patient safety issues while guaranteeing consideration of hand hygiene improvement as a high priority at all levels, including • active participation at both the institutional and individual levels; • awareness of individual and institutional capacity to change and improve (self-efficacy); and • partnership with patients and patient organisations.</td>
</tr>
</tbody>
</table>

An initiative idea
In addition to being asked to select the best way to implement the five components above on their own ward, each ward was encouraged to generate their own action plan for promoting hand hygiene on their own ward, possibly using measures that did not fit into any of the above five components.

\(^a\) Adapted from the WHO multimodal hand hygiene improvement strategy
(http://www.who.int/gpsc/5may/Guide_to_Implementation.pdf) \(^{46}\)

\(^b\) Point of care – The place where the patient, the health-care worker, and care or treatment involving contact with the patient or his/her surroundings occurs.
The step-wise approach of the WHO Multimodal Hand Hygiene Improvement Strategy \cite{46} was applied as part of the implementation process. This included 5 steps: step 1, facility preparedness – readiness for action; step 2, baseline evaluation – establishing knowledge of the current situation; step 3, implementation – introducing the improvement activities; step 4, follow-up evaluation – evaluating the implementation impact, and step 5, the ongoing planning and review cycle (Figure 5.1).

Figure 5.1: Implementation process summary: the WHO multimodal hand hygiene improvement strategy, the “My 5 Moments for Hand Hygiene” approach, and the step-wise approach. (from: \url{http://www.who.int/gpsc/5may/Guide_to_Implementation.pdf}) \cite{46}
5.2.6 Study procedures

Before starting this study:

Hand hygiene is considered as general and essential part of infection control practices.\(^{73}\)

Hand hygiene intervention programmes are one part of the regular work for infection control teams (ICTs) in Thailand\(^{69}\) and the hospital infection control departments were familiar with such interventions.\(^{69}\)

However, despite prior interventions, the study hospital had not been successful in attaining acceptable hand hygiene levels.\(^{69, 71, 86}\) It was anticipated that by actively engaging ward staff in designing their own interventions within the framework of the WHO multimodal strategy the limitations of previous interventions could be overcome. In this study the aim was, therefore, to work together with the hospital in implementing an intervention to improve hand hygiene compliance in HCWs and not intervene in their routine hospital work or require use of resources not usually available to them (since the aim was to develop a generalizable intervention that could be applied to other hospitals in LMICs).

Before starting this study, an overview of the study was given to the ICT and hospital director and their permission requested to perform the study including direct observation of hygiene practices for all HCWs. The meeting day for opening of the study by the hospital’s director was 8\(^{th}\) January 2013. At this meeting overall details of the study were given to the head nurses of all the study wards.

During this study:

This study was divided into 3 phases (Figure 5.2):

- Pre-intervention period: A 5-week baseline period where outcome data were recorded from all wards but no interventions were made.
- Intervention period: A 64-week intervention period during which the intervention was applied to each ward in turn.
- Post-intervention period: A 5-week follow-up period, where no further interventions were made but during which outcome data continued to be recorded

**Figure 5.2: Study phases**

![Diagram of study phases](image)

**Implementation of the intervention**

After the pre-intervention phase, the wards were randomized into the intervention step at one month intervals (Figure 5.3). The intervention was initially applied to one new randomly-selected ward each week during the intervention period. The order in which wards received the intervention was selected randomly using a computer generated randomization scheme.
**Figure 5.3:** Stepped wedge design of phase 2 of the hand hygiene intervention. Shaded cells represent intervention periods. All wards receive the intervention, but the ward receiving the intervention in a given week is selected randomly from those wards that have not yet received the intervention. Once wards have received the intervention they remain in the intervention arm.

One month prior to the intervention date for each ward they were notified by the research team and ICT (the ICT were responsible for delivering the intervention) requesting an appointment between the ICT and each ward to facilitate them designing an intervention plan to address the five components of the WHO intervention and to make plans to provide the training and other aspects of the intervention to ward staff. A new ward was selected at random for the intervention if the selected ward was currently closed (or expected to be closed at the intervention date). The notification included a summary of intervention details and procedures in two pages. All appointments took place as person-to-person meetings and appointments were arranged by phone calls to the wards. These meetings were also used to clarify the study information and requirements.
If the staff on the selected ward were unwilling or unable to receive the intervention on the specified date, then the randomly selected intervention week was still used for the intention to intervene analysis but the research team and ICT found an alternative date for the meeting with the ward staff. The window period for the intervention was considered to last from the start of the randomly selected intervention date until one month after this date. However, in case of delays in delivering the intervention the research team and ICT was also asked to record the date when the intervention was actually provided to the selected ward, and this date was used for a secondary per protocol analysis.

**Intervention procedure:**

- **One month before intervention date:** communication with randomized ward approximately one month before the intervention during the monthly meeting of head nurses (which occurs on the 20th of each month). This aimed to get three available days of infection control ward nurse (ICWN) or representative staff, who received the intervention in each ward intervention.

- **Day 1 of intervention week:** representatives of each ward were asked to present the current infection control practice and current situation with respect to hand hygiene practice of the ward to the head nurse and study team. This meeting should have included ICD, ICN, and research team and lasted around 30 minute. Then the study team explained the intervention menu and gave ward staff the intervention materials including the component menu and the Thai language translation of the manual “A Guide to the Implementation of the WHO Multimodal Hand Hygiene Improvement Strategy”.

- **Day 2 of intervention week:** the ICWN of each ward was coached and supported in making an action plan specific to their ward for promoting hand hygiene on their ward addressing the five components of the WHO strategy. The study team was also present at this meeting which lasted around 30 minutes. The ward staff members present at this meeting freely
decided to select which components in the intervention menu to implement taking into account the local circumstances in their ward and the overall need to address all five components of the WHO strategy.

- **Day 3 of intervention week:** the new plan of hand hygiene practice developed by ward staff was presented by the ICWN of the intervention ward to the head nurse and study team. This lasted around 30 minutes.

- **Within a month of intervention:** the implementing ward was required to set a meeting to explain the action plan to all ward staff, and each ward was asked to summarize the meeting and send a report to the ICT.

- **Every month after intention week:** implemented wards were asked to hold a meeting to re-assess the action plan with all staff and, if necessary, revise plans to promote hand hygiene under the supervision of the ICT.

**Fidelity to intervention**

Fidelity to intervention may be defined as the extent to which delivery of an intervention adheres to the origin protocol. The total number of the meeting reports that were returned to the ICT for updating action plans of the implemented intervention were considered as a measure of the fidelity to intervention.

Fidelity to intervention was also assessed by both direct ward-based observations by the research team and through interviews with the ICT. The ward-based observations of all study wards were performed by observers every week and allowed assessments of reminders in the work place and evidence of system change (for example, by assessing whether systems were in place to ensure alcohol handrub bottles were not empty, and soap and towels were available at sinks, or other facilities at point of care).

The ICT interviews were intended to be conducted with ward staff in all wards receiving the intervention one month after the intervention. These interviews also aimed to ensure that
the intervention was acceptable to staff and did not result in any unanticipated adverse consequences either for staff or patients.

5.2.7 Data Collection

Directly observed hand hygiene compliance data were collected during all three phases of the study by observers. Each observed session was performed in each ward in each week of the study. This required at least 58 observed sessions in this 58-ward study in each study week. Data on hand hygiene compliance from a minimum of five opportunities were collected from each ward during each week of the study.

As hand hygiene promotion was the current practice of infection control nurses and was standard practice throughout hospital site, this study aimed to assess the practice of hand hygiene without informing the participants that they are being watched. This was to reduce potential bias as previous studies provide strong evidence that HCWs will change their behavior if they know that they are being watched and that changed behavior is temporary and does not reflect the real practice (a Hawthorne effect).[102, 194]

Three months prior to staring the study, the observers were trained in observation methods to record hand hygiene compliance data. Observation methods were in accordance with WHO recommendations, using tools for training and education for observers provided by the WHO (http://www.who.int/gpsc/5may/tools/training_education/en/) and also making use of the WHO’s “5-movements” framework and the standard WHO hand hygiene compliance observation forms.[147, 102, 195] The “My 5 Moments for Hand Hygiene” approach encourages health-care workers to clean their hands (i) before touching a patient, (ii) before clean/aseptic procedures, (iii) after body fluid exposure/risk, (iv) after touching a patient and (v) after touching patient surroundings. Hand hygiene
observation data were entered daily on the secure password-protected study database, which was implemented in OpenClinica®.

### 5.2.8 Outcome measurements

The primary outcome was directly observed compliance with the WHO’s recommended five moments for hand hygiene amongst HCWs having direct patient contact. The compliance comparison was between pre-intervention and post-intervention rates of directly observed hand hygiene compliance within wards.

The trained observers collected the outcome data. Reliability among observers was assessed during the study to determine whether there was consistency in data collection between observers. Reliability among observers is often referred to as inter-observer reliability (inter-rater reliability). After two or more observers observe and document the same event, inter-rater reliability was determined by comparing the amount of agreement or disagreement in their assessments or measurements. Cohen’s kappa statistic was used to record inter-rater reliability between the observers.\(^{[170]}\) Cohen suggested the Kappa result be interpreted as follows: values ≤ 0 as indicating no agreement and 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement.\(^{[170]}\)

### 5.2.9 Statistical considerations

#### Sample size calculation

Power calculations were performed using equations 7 and 8 from Hussey & Hughes (2007).\(^{[104, 106]}\) Assuming 58 wards, and 60 one week time periods with the observation of at least of five of hand hygiene opportunities per ward per week throughout the study, the power to detect increases in hand hygiene compliance significant at the 5% level are given in Table 5.2 below.
These calculations assume extra binomial variation in hygiene compliance increases the outcome variance by a factor of two (such extra binomial variation could occur if staff are more likely to comply with hand hygiene guidelines if they see other staff complying with guidelines in the same period). Accounting for such extra binomial variation is conservative as it will decrease the power compared with the corresponding approach without such extra binomial variation.

These results show that the study had good power (>90%) to detect 2% increases in hand hygiene compliance if initial hand hygiene compliance was very low (~5%), and very high power to detect increases of 5% or more under all scenarios. They also confirm the observation that power in stepped wedge designs tends to be relatively insensitive to the intra cluster correlation coefficient (in contrast to parallel cluster randomized controlled trials).[104, 106]

**Table 5.2:** Power to detect increases in hand hygiene of compliance of 2 or 5% significant at the 5% level as a function of baseline hand hygiene compliance and the intra cluster correlation coefficient

<table>
<thead>
<tr>
<th>Baseline hand hygiene compliance</th>
<th>Increase in compliance after intervention</th>
<th>Intra cluster correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>5%</td>
<td>2%</td>
<td>93%</td>
</tr>
<tr>
<td>5%</td>
<td>5%</td>
<td>100%</td>
</tr>
<tr>
<td>10%</td>
<td>2%</td>
<td>70%</td>
</tr>
<tr>
<td>10%</td>
<td>5%</td>
<td>100%</td>
</tr>
<tr>
<td>15%</td>
<td>2%</td>
<td>55%</td>
</tr>
<tr>
<td>15%</td>
<td>5%</td>
<td>100%</td>
</tr>
<tr>
<td>20%</td>
<td>2%</td>
<td>46%</td>
</tr>
<tr>
<td>20%</td>
<td>5%</td>
<td>100%</td>
</tr>
<tr>
<td>30%</td>
<td>2%</td>
<td>37%</td>
</tr>
<tr>
<td>30%</td>
<td>5%</td>
<td>98%</td>
</tr>
</tbody>
</table>
**Statistical analysis**

The primary analysis was done on a per-protocol basis (using the dates at which each ward was randomized to receive the intervention). Response functions for modelling the effect of the intervention allowed for both changes in level and trend of outcome measures. The analysis was performed at the cluster level, with observations of hand hygiene compliance within each ward for each time period (week of study) and used a multilevel logistic regression model which is a type of generalized linear mixed model (GLMM). A GLMM is an extension to a generalized linear model (GLM) that accounts for random effects (random effects in this case are important for accounting for the fact that outcomes are more likely to be similar within each ward).

Analysis was performed using STATA version 14.0 (StataCorp LP, College station, Texas) and using the `melogit` command to fit a GLMM of the relationship between proportion of the hand hygiene compliance and intervention week. The command of the GLMM is:

```
melogit sum_overall Rx1 week post_ran i.week || ward:, binomial(sum_opp) or
```

As fixed effects, the intervention (Rx1 which is 0 in weeks before the intervention and 1 in weeks after the intervention), week, and post-intervention week number (week post_ran) entered into the model. This allowed the model to account for a stepwise changes associated with the intervention as well as pre-intervention and post-intervention trends. The categorical variables (i.week) also adjusted for week number, allowing for possible seasonal effects. In the random effect model, we assume the intercepts for the effect of intervention differ between the wards to account for the cluster effect of the wards (this is represented by “|| ward” in the STATA command). P-values were obtained using likelihood ratio tests comparing the full model with the effect in question against the model without the effect in question.

In the above command `sum_overall` is the number of total occasions of correctly performing hand hygiene in a particular ward in each week while `sum_opp` represents the number of opportunities.
The overall compliance for each ward in each week was calculated as the average compliance over all observed hand hygiene opportunities. The calculation of hand hygiene compliance was provided as follows:

\[
\text{Compliance (\%)} = \left( \frac{\text{Actual number of opportunities where correct HH was observed}}{\text{Number of the observed HH opportunities during observation}} \right) \times 100
\]

Additionally, an intention-to-intervene analysis (using the dates when wards actually received the intervention) was performed using the same multilevel logistic regression analysis accounting for clustering at the ward level. Subgroup analyses were performed for hand hygiene opportunities corresponding to each one of the “five moments”.

5.3 Results

5.3.1 Study flow

The trial start and finish date were specified as 24th December 2013 – 2nd May 2015 (a 74-week period). There were 57 wards included in 57 randomized steps (one step for each ward). The original plan had specified a 58-week intervention phase for implementing intervention, but one ward did not implement the intervention because an appointment to implement the intervention in the intervention phase could not be made.

Thirty-eight wards (65.5% [38/58]) initiated implementation of the intervention within one month of the time specified at randomization. There was a mean delay from the planned time of starting the intervention to the actual time of 1.1 weeks (interquartile range [IQR] 0-3 weeks, range 0-4 weeks).

Nineteen wards (32.8% [19/58]) had a delay in implementing the intervention that was greater than one month with a mean delay in implementation of 24.1 weeks (IQR 9-37 weeks, range 5-56 weeks).
weeks). To ensure that the last ward had a 5-week period of data collection post-intervention, the data collection was extended for all wards by six weeks to 2nd May 2015.

Reasons for these delays fell into two types: those reflecting hospital-wide factors which affected all wards, and ward specific factors. Hospital-wide factors were i) staff changes (a new head of each ward started on 1st of October of each year, and it was necessary to explain details of the study again to new ward heads); and ii) during hospital accreditation (all wards were requested by ICT to postpone interventions to prepare and perform activities for this accreditation event). Individual reasons included high workload and few staff available during the particular week a ward was randomized to receive the intervention. Figure 5.4 shows a timeline of the different study phases and actual weeks of implementation.

Inter-rater reliability was assessed before and during the study on a monthly basis by asking the observers to record hand hygiene compliance data independently during observation of the same hand hygiene opportunities. A total of 18 times of inter-rater reliability from the observers was assessed throughout the study period with a mean score of 0.928, which was considered as almost perfect agreement.[170] Appendix D.3 shows detail of all assessment of inter-rater reliability.

5.3.2 Number analyzed

For the outcome, intention-to-intervene analysis was performed for the 58 randomized wards into the intervention. An additional per-protocol analysis was also performed for the 57 implementing wards using the actual week of implementing the intervention.

If fidelity to intervention had been 100%, then, in addition to actually implementing interventions addressing each of five components of WHO strategy at the pre-specified time, each ward should have produced a report summarizing the outcome of the ward meeting to generate the action plan for improving hand hygiene practice in their ward for each of five intervention components, and
meeting reports after implementing the intervention which should have been returned to ICT every month or every time that they had a meeting. The total number of reports returned was 18, range 0-2 per ward, representing 7.0 % of the 258 reported expected from 57 wards. Data were available from all wards as to whether 0 or 1 report had been returned each month of the study. The assessment of fidelity by the research team found some implementing wards were doing activities to promote hand hygiene without sending any meeting reports to the ICT.

5.3.3 Hand hygiene compliance observations

A total of 4,206 hand hygiene observation sessions with a total of 20,709 repeatedly observed HCWs (Appendix D.4) were performed and there were 57,076 observed hand hygiene opportunities from 58 wards (Table 5.3, and Appendix D.5). The mean number of observed HCWs in these observation sessions was 1.1 (IQR 1-1 HCWs, range 1-5), and the mean number of observed opportunities per ward per week was 17.8 (IQR 11-22, range 1-90). A summary of the characteristics of all study wards is presented in Appendix D.6.

During the five pre-intervention weeks, there were 3,994 hand hygiene opportunities observed with an overall hand hygiene compliance rate of 8.89 % (355/3,994) and a ward-level weekly compliance ranging from a low of 0 % to a high of 100 %.

During the 64-week intervention period, 49,792 observations were made. In 5,142 of these hand hygiene compliance was observed (10.33%), and ward-level weekly rates ranged from 0% to 100%.

For the five post-intervention weeks, there were 3,290 observations, with an overall hand hygiene compliance rate of 9.67 %, (318 /3,290) with the ward-level weekly rates ranging from 0% to 100%. Figure 5.5 presents the hand hygiene compliance data for each ward in the study.
Figure 5.4: Timeline of study period for randomization and implementation

Note: Dark blue is pre-intervention period. Dark red is randomized week. Green is period of delayed implementation. Orange is actual implementation period. Grey is post-intervention period.
While overall changes in compliance were small, improvements in hand hygiene compliance were found in 27 wards after implementing the intervention, and in five wards the intervention was associated with a doubling of their pre-intervention compliance rate. Appendix D.7 presents the change in hand hygiene compliance comparing values before and after the intervention for each ward.

More than half of the observed hand hygiene opportunities came from registered nurses (54.96% [31,369/57,076]), followed by nursing aides (19.03% [10,863/57,076]), and hospital support staff, who are responsible to clean around the patient zone (6.85% [3,911/57,076]). While only 20 of 57 wards were ICU wards these accounted for the majority of observed hand hygiene opportunities (67.32% [38,425/57,076]), while one third of observed opportunities (32.67% [18,651/57,076]) came from the 37 non-ICU wards (Table 5.3). Summaries of all observed HCWs by characteristics and covariates in the study are shown in Appendix D.8, while characteristic of HCWs are presented in Table 5.4.

The highest improvement in hand hygiene compliance was for visitors (3.52% before intervention vs. 7.41% after intervention), followed by physicians (5.41% before intervention vs. 8.21% of after intervention), and nursing aides (4.12% before intervention vs. 6.90% after interventions). The rate of hand hygiene compliance in the department of obstetrics and gynecology nearly doubled (3.07% of before intervention vs. 6.92% of after intervention) (Appendix D.9). Comparisons of hand hygiene compliance by characteristic variables and before and after the intervention are presented in Appendix D.9, Appendix D.10, and Appendix D.11.
Table 5.3: Descriptive opportunity for hand hygiene by characteristics and covariates in the study

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before intervention</th>
<th></th>
<th>After intervention</th>
<th></th>
<th>Overall</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not performed</td>
<td>Performed</td>
<td>Total</td>
<td>Not performed</td>
<td>Performed</td>
<td>Total</td>
</tr>
<tr>
<td>Overall</td>
<td>30,954 (89.9%)</td>
<td>3,476 (10.1%)</td>
<td>34,430 (100%)</td>
<td>20,307 (89.7%)</td>
<td>2,339 (10.3%)</td>
<td>22,646 (100%)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>7,419 (94.7%)</td>
<td>418 (5.3%)</td>
<td>7,837 (100%)</td>
<td>3,572 (92.2%)</td>
<td>302 (7.8%)</td>
<td>3,874 (100%)</td>
</tr>
<tr>
<td>Female</td>
<td>23,535 (88.5%)</td>
<td>3,058 (11.5%)</td>
<td>26,593 (100%)</td>
<td>16,735 (89.1%)</td>
<td>2,037 (10.9%)</td>
<td>18,772 (100%)</td>
</tr>
<tr>
<td>Type of HCW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctor</td>
<td>1,730 (94.6%)</td>
<td>99 (5.4%)</td>
<td>1,829 (100%)</td>
<td>559 (91.8%)</td>
<td>50 (8.2%)</td>
<td>609 (100%)</td>
</tr>
<tr>
<td>Registered Nurse</td>
<td>15,979 (85.4%)</td>
<td>2,723 (14.6%)</td>
<td>18,702 (100%)</td>
<td>11,003 (86.9%)</td>
<td>1,664 (13.1%)</td>
<td>12,667 (100%)</td>
</tr>
<tr>
<td>Technical Nurse</td>
<td>515 (87.6%)</td>
<td>73 (12.4%)</td>
<td>588 (100%)</td>
<td>446 (88.1%)</td>
<td>60 (11.9%)</td>
<td>506 (100%)</td>
</tr>
<tr>
<td>Nursing Assistant</td>
<td>1,560 (94.0%)</td>
<td>99 (6.0%)</td>
<td>1,659 (100%)</td>
<td>1,133 (91.9%)</td>
<td>100 (8.1%)</td>
<td>1,233 (100%)</td>
</tr>
<tr>
<td>Nursing Aide</td>
<td>6,287 (95.9%)</td>
<td>270 (4.1%)</td>
<td>6,557 (100%)</td>
<td>4,009 (93.1%)</td>
<td>297 (6.9%)</td>
<td>4,306 (100%)</td>
</tr>
<tr>
<td>Hospital support staff</td>
<td>2,012 (96.0%)</td>
<td>83 (4.0%)</td>
<td>2,095 (100%)</td>
<td>1,721 (94.8%)</td>
<td>95 (5.2%)</td>
<td>1,816 (100%)</td>
</tr>
<tr>
<td>Medical Student</td>
<td>406 (97.1%)</td>
<td>12 (2.9%)</td>
<td>418 (100%)</td>
<td>100 (99.0%)</td>
<td>1 (1.0%)</td>
<td>101 (100%)</td>
</tr>
<tr>
<td>Nursing Student</td>
<td>1,287 (94.6%)</td>
<td>74 (5.4%)</td>
<td>1,361 (100%)</td>
<td>1,036 (95.6%)</td>
<td>48 (4.4%)</td>
<td>1,084 (100%)</td>
</tr>
<tr>
<td>Visitor</td>
<td>1,178 (96.5%)</td>
<td>43 (3.5%)</td>
<td>1,221 (100%)</td>
<td>300 (92.6%)</td>
<td>24 (7.4%)</td>
<td>324 (100%)</td>
</tr>
<tr>
<td>Ward type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ICU wards</td>
<td>20,839 (93.3%)</td>
<td>1,497 (6.7%)</td>
<td>22,336 (100%)</td>
<td>14,698 (91.4%)</td>
<td>1,391 (8.6%)</td>
<td>16,089 (100%)</td>
</tr>
<tr>
<td>ICU wards</td>
<td>10,115 (83.6%)</td>
<td>1,979 (16.4%)</td>
<td>12,094 (100%)</td>
<td>5,609 (85.5%)</td>
<td>948 (14.5%)</td>
<td>6,557 (100%)</td>
</tr>
</tbody>
</table>
Table 5.3: Descriptive opportunity for hand hygiene by characteristics and covariates in the study (cont.)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before intervention</th>
<th></th>
<th>After intervention</th>
<th></th>
<th>Overall</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>Performed (%)</td>
<td>Total</td>
<td>n (%)</td>
<td>Performed (%)</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>Not performed</td>
<td>Performed</td>
<td>Total</td>
<td>Not performed</td>
<td>Performed</td>
<td>Total</td>
</tr>
<tr>
<td>Department</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obstetrics and gynecology</td>
<td>662 (96.9%)</td>
<td>21 (3.1%)</td>
<td>683 (100%)</td>
<td>2,569 (93.1%)</td>
<td>191 (6.9%)</td>
<td>2,760 (100%)</td>
</tr>
<tr>
<td>Eye</td>
<td>120 (68.6%)</td>
<td>55 (31.4%)</td>
<td>175 (100%)</td>
<td>558 (71.0%)</td>
<td>228 (29.0%)</td>
<td>786 (100%)</td>
</tr>
<tr>
<td>Ear Nose Throat</td>
<td>223 (91.8%)</td>
<td>20 (8.2%)</td>
<td>243 (100%)</td>
<td>504 (86.2%)</td>
<td>81 (13.8%)</td>
<td>585 (100%)</td>
</tr>
<tr>
<td>Paediatrics</td>
<td>2,822 (82.6%)</td>
<td>596 (17.4%)</td>
<td>3,418 (100%)</td>
<td>4,105 (85.4%)</td>
<td>699 (14.6%)</td>
<td>4,804 (100%)</td>
</tr>
<tr>
<td>Medicine</td>
<td>10,255 (92.6%)</td>
<td>816 (7.4%)</td>
<td>11,071 (100%)</td>
<td>6,969 (93.6%)</td>
<td>480 (6.4%)</td>
<td>7,449 (100%)</td>
</tr>
<tr>
<td>Surgery</td>
<td>16,872 (89.6%)</td>
<td>1,968 (10.4%)</td>
<td>18,840 (100%)</td>
<td>5,602 (89.5%)</td>
<td>660 (10.5%)</td>
<td>6,262 (100%)</td>
</tr>
<tr>
<td>Indication for performing hand hygiene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before touching a patient</td>
<td>7,516 (95.1%)</td>
<td>388 (4.9%)</td>
<td>7,904 (100%)</td>
<td>4,440 (92.5%)</td>
<td>362 (7.5%)</td>
<td>4,802 (100%)</td>
</tr>
<tr>
<td>After touching a patient</td>
<td>7,012 (90.1%)</td>
<td>769 (9.9%)</td>
<td>7,781 (100%)</td>
<td>4,192 (89.2%)</td>
<td>505 (10.8%)</td>
<td>4,697 (100%)</td>
</tr>
<tr>
<td>Before clean/aseptic procedures</td>
<td>3,679 (86.2%)</td>
<td>587 (13.8%)</td>
<td>4,266 (100%)</td>
<td>2,238 (85.9%)</td>
<td>366 (14.1%)</td>
<td>2,604 (100%)</td>
</tr>
<tr>
<td>After body fluid exposure/risk</td>
<td>3,726 (77.9%)</td>
<td>1,054 (22.1%)</td>
<td>4,780 (100%)</td>
<td>2,133 (79.9%)</td>
<td>535 (20.1%)</td>
<td>2,668 (100%)</td>
</tr>
<tr>
<td>After touching patient surroundings</td>
<td>9,021 (93.0%)</td>
<td>678 (7.0%)</td>
<td>9,699 (100%)</td>
<td>7,304 (92.7%)</td>
<td>571 (7.3%)</td>
<td>7,875 (100%)</td>
</tr>
</tbody>
</table>
Figure 5.5: Hand-hygiene compliance in each ward by week. The white line shows the actual week when the intervention was initiated.
Table 5.4: Descriptive statistics for characteristics and covariates in the study by observed HCWs [n]

<table>
<thead>
<tr>
<th>Variables</th>
<th>Overall (n = 3,272)</th>
<th>Overall (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1,039</td>
<td>31.75</td>
</tr>
<tr>
<td>Female</td>
<td>2,233</td>
<td>68.25</td>
</tr>
<tr>
<td>Type of HCWs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctor</td>
<td>461</td>
<td>14.09</td>
</tr>
<tr>
<td>Registered Nurse</td>
<td>970</td>
<td>29.65</td>
</tr>
<tr>
<td>Technical Nurse</td>
<td>35</td>
<td>1.07</td>
</tr>
<tr>
<td>Nursing Assistant</td>
<td>60</td>
<td>1.83</td>
</tr>
<tr>
<td>Nursing Aide</td>
<td>288</td>
<td>8.8</td>
</tr>
<tr>
<td>Hospital supported staff</td>
<td>208</td>
<td>6.36</td>
</tr>
<tr>
<td>Medical Student</td>
<td>147</td>
<td>4.49</td>
</tr>
<tr>
<td>Nursing Student</td>
<td>644</td>
<td>19.68</td>
</tr>
<tr>
<td>Visitor</td>
<td>459</td>
<td>14.03</td>
</tr>
<tr>
<td>Ward type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ICU wards</td>
<td>2,219</td>
<td>67.82</td>
</tr>
<tr>
<td>ICU wards</td>
<td>1,053</td>
<td>32.18</td>
</tr>
<tr>
<td>Department</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obstetrics and gynecology</td>
<td>216</td>
<td>6.6</td>
</tr>
<tr>
<td>Eye</td>
<td>45</td>
<td>1.38</td>
</tr>
<tr>
<td>Ear Nose Throat</td>
<td>50</td>
<td>1.53</td>
</tr>
<tr>
<td>Paediatrics</td>
<td>517</td>
<td>15.8</td>
</tr>
<tr>
<td>Medicine</td>
<td>1,084</td>
<td>33.13</td>
</tr>
<tr>
<td>Surgery</td>
<td>1,360</td>
<td>41.56</td>
</tr>
</tbody>
</table>
**Overall impact of the intervention**

In the primary intention-to-intervene analysis the intervention was associated with an improvement in hand hygiene compliance, but the effect was small (Odds ratio [OR] 1.12; 95% confidence interval [CI] 1.01 to 1.24, \( p = 0.027 \)) (Table 5.5). Overall hand hygiene compliance rates were similar during the pre-intervention phase (10.09% \( [3,467/34,434] \)) and during the post-intervention phase (10.33% \( [2,339/22,642] \)).

The majority of hand hygiene compliance rates observed were less than 20% (shown in red in Figure 5.5) with similar hand hygiene compliance before and after the actual intervention date (the white line indicates the actual time the intervention was initiated in each ward).

In the first six months of the study, the rate of hand hygiene compliance differed slightly between those wards which had implemented the intervention and those which hadn't, while the rate of hand hygiene compliance was similar between these two groups of wards in the last six month of intervention period (Figure 5.6 and Figure 5.7).

**Table 5.5:** Estimated odds ratios (95% CI) associated with the intervention allowing for effect modification by individual ward in a model excluding potential confounders (intention-to-intervene analysis)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Estimated odds ratio</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before randomisation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After randomisation</td>
<td>1.12</td>
<td>1.01 to 1.24</td>
<td>0.027</td>
</tr>
<tr>
<td>Week number</td>
<td>1.01</td>
<td>1.01 to 1.02</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Week after randomisation</td>
<td>1.00</td>
<td>1.00 to 1.01</td>
<td>0.314</td>
</tr>
</tbody>
</table>
Per-protocol analysis in implementing wards showed similar findings to the intention-to-intervene analysis (OR 1.11; 95% CI 1.00 to 1.22, p = 0.043) (Table 5.6). From 57 wards of this analysis, hand hygiene compliance was observed at a similar rate during the intervention (10.22% [1,935/18,932] vs. 10.45% [2,008/19,210]).

Table 5.6: Estimated odds ratios (95% CI) of hand hygiene compliance associated with the intervention allowing for effect modification by individual ward (per-protocol analysis)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Estimated odds ratio</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before implementation</td>
<td>Reference</td>
<td>1.00 to 1.22</td>
<td>0.043</td>
</tr>
<tr>
<td>After implementation</td>
<td>1.11</td>
<td>1.00 to 1.22</td>
<td></td>
</tr>
<tr>
<td>Week number</td>
<td>1.01</td>
<td>1.01 to 1.02</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Week after implementation</td>
<td>1.00</td>
<td>1.00 to 1.00</td>
<td>0.535</td>
</tr>
</tbody>
</table>
Impact of the intervention in ICU and non-ICU wards

The rates of hand hygiene compliance in ICU wards were slightly higher than non-ICU wards (Figure 5.6 and Table 5.7).

In the initial intention-to-intervene analysis the estimated odds ratio for an increase in hand hygiene compliance between ICU wards (OR 1.07; 95% CI 0.93 to 1.24, p = 0.335) and non-ICU wards (OR 1.15; 95% CI 1.00 to 1.33, p = 0.048) was found to be similar.

Table 5.7: Estimated odds ratios (95% CI) of hand hygiene compliance associated with the intervention allowing for effect modification by intensive-care unit in a model excluding potential confounders (intention-to-intervene analysis)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Estimated odds ratio</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Non-ICU wards</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before randomisation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After randomisation</td>
<td>1.15</td>
<td>1.00 to 1.33</td>
<td>0.048</td>
</tr>
<tr>
<td>Week number</td>
<td>1.01</td>
<td>1.00 to 1.02</td>
<td>0.004</td>
</tr>
<tr>
<td>Week after randomisation</td>
<td>1.00</td>
<td>1.00 to 1.01</td>
<td>0.136</td>
</tr>
<tr>
<td><strong>ICU wards</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before randomisation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After randomisation</td>
<td>1.07</td>
<td>0.93 to 1.24</td>
<td>0.335</td>
</tr>
<tr>
<td>Week number</td>
<td>1.01</td>
<td>1.00 to 1.02</td>
<td>0.059</td>
</tr>
<tr>
<td>Week after randomisation</td>
<td>1.00</td>
<td>0.99 to 1.00</td>
<td>0.612</td>
</tr>
</tbody>
</table>
Per-protocol analysis in implementing wards showed similar effect of the intervention on hand hygiene compliance in ICU wards (OR 1.13; 95% CI 0.97 to 1.31, p = 0.126) and non-ICU wards (OR 1.11; 95% CI 0.97 to 1.26, p = 0.146) (Table 5.8).

**Table 5.8:** Estimated odds ratios (95% CI) of hand hygiene compliance associated with the intervention allowing for effect modification by intensive-care unit (per-protocol analysis).

<table>
<thead>
<tr>
<th>Factor</th>
<th>Estimated odds ratio</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-ICU wards</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before implementation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After implementation</td>
<td>1.11</td>
<td>0.97 to 1.26</td>
<td>0.146</td>
</tr>
<tr>
<td>Week number</td>
<td>1.02</td>
<td>1.01 to 1.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Week after implementation</td>
<td>1.00</td>
<td>0.99 to 1.00</td>
<td>0.821</td>
</tr>
<tr>
<td><strong>ICU wards</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before implementation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After implementation</td>
<td>1.13</td>
<td>0.97 to 1.31</td>
<td>0.126</td>
</tr>
<tr>
<td>Week number</td>
<td>1.01</td>
<td>1.00 to 1.02</td>
<td>0.046</td>
</tr>
<tr>
<td>Week after implementation</td>
<td>1.00</td>
<td>0.99 to 1.00</td>
<td>0.129</td>
</tr>
</tbody>
</table>
Figure 5.6: Hand-hygiene compliance in ICU wards (left panel) and non-ICU wards (right panel): intention-to-intervene analysis
**Figure 5.7:** Hand-hygiene compliance in ICU wards (left panel) and non-ICU wards (right panel): per-protocol analysis
Impact of the intervention by department

The rate of hand hygiene was different in different departments. In the intention-to-intervene analysis, estimated odds ratios of the intervention allowing for effect modification by department, showed that the highest estimated odds ratio associated with the intervention was in the department of obstetrics and gynecology where there was evidence of a substantial increase in hand hygiene compliance (OR 3.96; 95% CI 1.88 to 8.31, p<0.001). A substantial positive effect was also seen in the department of pediatrics, while the lowest impact was found in the department of medicine where compliance declined (OR 0.78; 95% CI 0.61 to 0.99, p = 0.044) (Table 5.9).

Per-protocol analysis in implementing wards estimated odds ratios of the intervention allowing for effect modification by department and showed smaller effects than the result of the intention-to-intervene analysis for the department of obstetrics and gynecology (OR 2.43; 95% CI 1.05 to 5.63, p = 0.038), but a higher effect was found in the department of medicine (OR 0.82; 95% CI 0.66 to 1.02, p = 0.078) (Table 5.10).
Table 5.9: Estimated odds ratios (95% CI) of hand hygiene compliance associated with the intervention allowing for effect modification by department – subgroup analysis (intention-to-intervene analysis)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Estimated odds ratio</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Department of Obstetrics and gynecology</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before randomisation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After randomisation</td>
<td>3.96</td>
<td>1.88 to 8.31</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Week number</td>
<td>0.97</td>
<td>0.91 to 1.04</td>
<td>0.384</td>
</tr>
<tr>
<td>Week after randomisation</td>
<td>1.04</td>
<td>0.97 to 1.11</td>
<td>0.258</td>
</tr>
<tr>
<td><strong>Department of Paediatrics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before randomisation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After randomisation</td>
<td>1.71</td>
<td>1.18 to 2.48</td>
<td>0.005</td>
</tr>
<tr>
<td>Week number</td>
<td>0.98</td>
<td>0.95 to 1.03</td>
<td>0.465</td>
</tr>
<tr>
<td>Week after randomisation</td>
<td>1.04</td>
<td>0.99 to 1.08</td>
<td>0.110</td>
</tr>
<tr>
<td><strong>Department of Medicine</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before randomisation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After randomisation</td>
<td>0.78</td>
<td>0.61 to 0.99</td>
<td>0.044</td>
</tr>
<tr>
<td>Week number</td>
<td>1.00</td>
<td>0.99 to 1.02</td>
<td>0.576</td>
</tr>
<tr>
<td>Week after randomisation</td>
<td>0.99</td>
<td>0.98 to 1.00</td>
<td>0.065</td>
</tr>
<tr>
<td><strong>Department of Surgery</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before randomisation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After randomisation</td>
<td>1.07</td>
<td>0.89 to 1.30</td>
<td>0.460</td>
</tr>
<tr>
<td>Week number</td>
<td>1.01</td>
<td>1.01 to 1.02</td>
<td>0.004</td>
</tr>
<tr>
<td>Week after randomisation</td>
<td>1.01</td>
<td>1.00 to 1.02</td>
<td>0.290</td>
</tr>
</tbody>
</table>
Table 5.10: Estimated odds ratios (95% CI) of hand hygiene compliance associated with the intervention allowing for effect modification by department – subgroup analysis (per-protocol analysis)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Estimated odds ratio</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Department of Obstetrics and gynecology</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before implementation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After implementation</td>
<td>2.43</td>
<td>1.05 to 5.63</td>
<td>0.03</td>
</tr>
<tr>
<td>Week number</td>
<td>1.00</td>
<td>0.95 to 1.06</td>
<td>0.96</td>
</tr>
<tr>
<td>Week after implementation</td>
<td>1.01</td>
<td>0.97 to 1.06</td>
<td>0.63</td>
</tr>
<tr>
<td><strong>Department of Paediatrics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before implementation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After implementation</td>
<td>1.18</td>
<td>0.93 to 1.50</td>
<td>0.17</td>
</tr>
<tr>
<td>Week number</td>
<td>1.02</td>
<td>1.01 to 1.04</td>
<td>0.00</td>
</tr>
<tr>
<td>Week after implementation</td>
<td>1.00</td>
<td>0.99 to 1.00</td>
<td>0.43</td>
</tr>
<tr>
<td><strong>Department of Medicine</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before implementation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After implementation</td>
<td>0.82</td>
<td>0.66 to 1.02</td>
<td>0.07</td>
</tr>
<tr>
<td>Week number</td>
<td>1.00</td>
<td>0.99 to 1.01</td>
<td>0.94</td>
</tr>
<tr>
<td>Week after implementation</td>
<td>0.99</td>
<td>0.98 to 1.00</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Department of Surgery</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before implementation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After implementation</td>
<td>1.12</td>
<td>0.93 to 1.35</td>
<td>0.23</td>
</tr>
<tr>
<td>Week number</td>
<td>1.02</td>
<td>1.01 to 1.03</td>
<td>&lt;0.0</td>
</tr>
<tr>
<td>Week after implementation</td>
<td>1.00</td>
<td>0.99 to 1.01</td>
<td>0.53</td>
</tr>
</tbody>
</table>
5.3.4 Hand hygiene compliance by “My five moments for hand hygiene”

The most commonly observed moment for hand hygiene was the indication of ‘after touching patient surroundings’ (30.79% [17,574/57,076]), followed by the indication of ‘before touching a patient’ (22.26% [12,706/57,076]) (Table 5.3).

In intention-to-treat analysis, the highest effects of the intervention were found in the indication ‘before touching a patient’ with an estimated odds ratio of 1.73 (95% CI 1.32 to 2.25, p<0.001), while the smallest effect was found in the indication ‘after body fluid exposure/risk’ with an estimated odds ratio of 0.97 (95% CI 0.78 to 1.20, p = 0.752). Table 5.11 shows the estimated odds ratios for hand hygiene compliance according to the specific moment under the intention-to-intervene analysis.

Per-protocol analysis in implementing wards adjusting for indication for hand hygiene showed a similar finding in the estimated odds of hand hygiene compliance. Table 5.12 shows the estimated odds ratio for hand hygiene compliance according the hand hygiene moment under the per-protocol analysis.
Table 5.11: Estimated odds ratios (95% CI) for hand hygiene compliance associated with the intervention according to hand hygiene opportunity type (intention-to-intervene analysis)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Estimated odds ratio</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before touching a patient</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before randomisation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After randomisation</td>
<td>1.72</td>
<td>1.32 to 2.25</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Week number</td>
<td>1.01</td>
<td>0.99 to 1.03</td>
<td>0.451</td>
</tr>
<tr>
<td>Week after randomisation</td>
<td>1.00</td>
<td>0.99 to 1.01</td>
<td>0.572</td>
</tr>
<tr>
<td><strong>After touching a patient</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before randomisation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After randomisation</td>
<td>1.09</td>
<td>0.89 to 1.35</td>
<td>0.397</td>
</tr>
<tr>
<td>Week number</td>
<td>1.00</td>
<td>0.99 to 1.01</td>
<td>0.862</td>
</tr>
<tr>
<td>Week after randomisation</td>
<td>1.01</td>
<td>1.00 to 1.01</td>
<td>0.305</td>
</tr>
<tr>
<td><strong>Before clean/aseptic procedures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before randomisation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After randomisation</td>
<td>1.17</td>
<td>0.90 to 1.52</td>
<td>0.234</td>
</tr>
<tr>
<td>Week number</td>
<td>1.02</td>
<td>0.99 to 1.05</td>
<td>0.114</td>
</tr>
<tr>
<td>Week after randomisation</td>
<td>1.01</td>
<td>1.00 to 1.03</td>
<td>0.151</td>
</tr>
<tr>
<td><strong>After body fluid exposure/risk</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before randomisation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After randomisation</td>
<td>0.97</td>
<td>0.78 to 1.20</td>
<td>0.752</td>
</tr>
<tr>
<td>Week number</td>
<td>1.02</td>
<td>1.00 to 1.03</td>
<td>0.045</td>
</tr>
<tr>
<td>Week after randomisation</td>
<td>1.00</td>
<td>0.99 to 1.02</td>
<td>0.545</td>
</tr>
<tr>
<td><strong>After touching patient surroundings</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before randomisation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After randomisation</td>
<td>1.06</td>
<td>0.87 to 1.28</td>
<td>0.569</td>
</tr>
<tr>
<td>Week number</td>
<td>1.01</td>
<td>1.00 to 1.03</td>
<td>0.051</td>
</tr>
<tr>
<td>Week after randomisation</td>
<td>0.99</td>
<td>0.98 to 1.00</td>
<td>0.100</td>
</tr>
</tbody>
</table>
Table 5.12: Estimated odds ratios (95% CI) for hand hygiene compliance associated with the intervention according to hand hygiene opportunity type (per-protocol analysis)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Estimated odds ratio</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before touching a patient</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before implementation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After implementation</td>
<td>1.44</td>
<td>1.11 to 1.86</td>
<td>0.006</td>
</tr>
<tr>
<td>Week number</td>
<td>1.01</td>
<td>1.00 to 1.03</td>
<td>0.133</td>
</tr>
<tr>
<td>Week after implementation</td>
<td>0.99</td>
<td>0.99 to 1.00</td>
<td>0.254</td>
</tr>
<tr>
<td><strong>After touching a patient</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before implementation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After implementation</td>
<td>1.06</td>
<td>0.86 to 1.31</td>
<td>0.579</td>
</tr>
<tr>
<td>Week number</td>
<td>1.00</td>
<td>0.99 to 1.02</td>
<td>0.519</td>
</tr>
<tr>
<td>Week after implementation</td>
<td>1.00</td>
<td>0.99 to 1.01</td>
<td>0.887</td>
</tr>
<tr>
<td><strong>Before clean/aseptic procedures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before implementation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After implementation</td>
<td>1.22</td>
<td>0.94 to 1.58</td>
<td>0.141</td>
</tr>
<tr>
<td>Week number</td>
<td>1.03</td>
<td>1.00 to 1.06</td>
<td>0.076</td>
</tr>
<tr>
<td>Week after implementation</td>
<td>1.00</td>
<td>0.99 to 1.02</td>
<td>0.689</td>
</tr>
<tr>
<td><strong>After body fluid exposure/risk</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before implementation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After implementation</td>
<td>0.99</td>
<td>0.79 to 1.23</td>
<td>0.921</td>
</tr>
<tr>
<td>Week number</td>
<td>1.02</td>
<td>1.01 to 1.03</td>
<td>0.019</td>
</tr>
<tr>
<td>Week after implementation</td>
<td>1.00</td>
<td>0.99 to 1.01</td>
<td>0.495</td>
</tr>
<tr>
<td><strong>After touching patient surroundings</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before implementation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After implementation</td>
<td>1.07</td>
<td>0.88 to 1.30</td>
<td>0.491</td>
</tr>
<tr>
<td>Week number</td>
<td>1.01</td>
<td>1.00 to 1.02</td>
<td>0.088</td>
</tr>
<tr>
<td>Week after implementation</td>
<td>1.00</td>
<td>0.99 to 1.00</td>
<td>0.296</td>
</tr>
</tbody>
</table>
5.3.5 Effectiveness of a multimodal hand hygiene improvement strategy

All 57 wards (100%) implemented the intervention by applying the ‘system change’ and the ‘reminders in the workplace’. Only four wards implemented the intervention by applying the ‘institutional safety climate’. Only two wards implemented the intervention by applying all five multimodal hand hygiene improvement strategies during the study (Table 5.13).

Table 5.13: The intervention implementation by applying multimodal hand hygiene improvement strategy

<table>
<thead>
<tr>
<th>Factors</th>
<th>Total wards</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Change</td>
<td>57</td>
<td>100</td>
</tr>
<tr>
<td>Training / Education</td>
<td>27</td>
<td>47.37</td>
</tr>
<tr>
<td>Evaluation and feedback</td>
<td>38</td>
<td>66.67</td>
</tr>
<tr>
<td>Reminders in the workplace</td>
<td>57</td>
<td>100</td>
</tr>
<tr>
<td>Institutional safety climate</td>
<td>4</td>
<td>7.02</td>
</tr>
</tbody>
</table>

Analysis in implementing wards showed the strongest association after implementing the component of ‘Reminders in workplace’ with an estimated odds ratio of 2.55 (95% CI 1.62 to 4.01, p<0.001). This component was implemented in all implemented wards by the research team proving a set of visual reminders and education to all implementing wards as study materials including posters, leaflets, flipcharts and video that covered (i) my 5 moments for hand hygiene; (ii) handwashing/handrubbing steps; (iii) gloves using; (iv) transmission of healthcare associated pathogens; and (v) impact of HCAI. The component of ‘Training / Education’ provided the lowest association with an estimated odds ratio of 0.89 (95% CI 0.76 to 1.04, p=134) (Table 5.14).
Table 5.14: Estimated odds ratios (95% CI) for hand hygiene compliance associated with the intervention components

<table>
<thead>
<tr>
<th>Factor</th>
<th>Estimated odds ratio</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before randomisation</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Change</td>
<td>1.05</td>
<td>0.95 to 1.19</td>
<td>0.317</td>
</tr>
<tr>
<td>Training / Education</td>
<td>0.89</td>
<td>0.76 to 1.04</td>
<td>0.134</td>
</tr>
<tr>
<td>Evaluation and feedback</td>
<td>1.24</td>
<td>1.07 to 1.44</td>
<td>0.004</td>
</tr>
<tr>
<td>Reminders in the workplace</td>
<td>2.55</td>
<td>1.62 to 4.01</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Institutional safety climate</td>
<td>1.44</td>
<td>1.10 to 1.88</td>
<td>0.007</td>
</tr>
</tbody>
</table>

5.4 Discussion

5.4.1 Key findings

The principle findings of this trial were that a multimodal hand hygiene improvement intervention, designed using a stepped wedge randomized control design with active engagement of ward staff in designing the action plan to induce behaviour change in ward level, produced a small improvement in hand hygiene in both intention-to-intervene and per-protocol analyses.

The reasons for the quite disappointing levels of improvement might come from the several difficulties of implementation, including factors at the ward and hospital level. Some evidence of clinically significant improvements in individual wards is found, and this could be related with greater success in changing the ward-based culture or high-level co-operation in the ward from all ward staff.

To our knowledge, this is the first randomized controlled trial applying the WHO hand hygiene intervention outside high income countries. While the improvements were small, and probably of limited overall clinical significance, the study establishes the feasibility to apply the WHO strategy to promote hand hygiene in resource limited settings and also suggests the need for more active
engagement from administrators in making, prioritizing and integrating the action plan into standard policies.

### 5.4.2 Comparison of findings with other studies

The difficulties in implementing the intervention as planned are consistent with the findings of the FIT study by Fuller et al.[108], which reported that infection control at the ward was perceived as having lower priority than other work. The difficulty for delivering the intervention comes from several reasons including individual reasons (knowledge, wrong beliefs on hand hygiene, awareness, emotion) and institutional reasons reasons (lacking of supplies, staffing, and high workload).

Several studies have proposed that ward-based or team–based strategies could be a key strategy to promote hand hygiene by taking advantage of the social context of each setting and it has been claimed that this approach is underpinned by theories from behavioural science. [196] This idea suggests that greater success in implementation of the intervention could be achieved if there were an action plan focusing on each ward and holding workshops to discuss the workflow of each ward to make a ward-specific plan. [196] Following this suggestion Huis et al. found high improvement in particular wards that were successful in making culture changes at the ward to make staff more aware of performing hand hygiene. In this study, there were also examples of creative idea to promote hand hygiene. For example, some wards set a hand hygiene day in every month. On these days there were activities to promote hand hygiene in the ward in a similar manner to the annual hospital hand hygiene day (activities included reminders between HCWs and education and practice sessions). Other wards had representatives of each HCW type involved in the design of the action plan to promote hand hygiene in their role.

Comparative efficacy of the WHO strategy to promote hand hygiene in hospitals between 1980 and 2009 is reported in a systemic review by Luangasanatip et al.[82], which analysed data from
high quality intervention studies (including randomized controlled trials, interrupted time series, non-randomized trials, and controlled before-after studies). Network meta-analysis from this review indicated considerable uncertainty in the relative effectiveness of interventions, but nonetheless provided evidence that WHO strategy is effective and that compliance can be further improved by adding interventions including goal setting, reward incentives, and accountability. In some successful wards in this study, goal-setting was used as an additional intervention: two wards chose to have routine meetings to evaluate the intervention plan, revise the goals and plan to achieve the target rates of hand hygiene.

5.4.3 Strengths, limitations and future directions

The principle strength of the study is the strong design used to evaluate the impact of the WHO strategy: by using a stepped wedge design each ward compares their own compliance at different time points, pre and post-intervention. This design, a type of cluster randomized trial, also meets requirements of the previous systematic review of high quality studies. This study also implemented the intervention hospital-wide in a resource limited hospital, while most previous studies from LMICs have evaluated interventions only in more restricted study populations.

The study’s main limitation was that the intervention was more difficult to implement than anticipated despite high level support for the intervention in the hospital. Two other studies have mentioned a lack of concern or belief in hand hygiene being able to prevent HCAI as a main source of difficulty. This appears to be one of the difficulties of this study as well, based on the qualitative research described in the previous chapters. In another study, the impact of a team and leaders-directed strategy to improve hand hygiene was evaluated in a cluster randomized controlled trial. This proved to be successful in improving hand hygiene but the authors also reported the difficulties in the participating wards due to higher priority work. Such competing priorities were likely a key issue in this study as well, and were one reason for the delays in the intervention. Intervention to
improve hand hygiene compliance (or maintain it at high level) is an integral part of hospital infection control, and the hospital infection control staff is the responsible people to deliver the intervention. In this study the ICT were not always able to obtain the co-operation of the majority of ward staff despite high-level endorsement of the intervention by the hospital director. This is likely to be a key reason the intervention was not successful at achieving larger improvements in hand hygiene.

A second limitation was the possibility of contamination between clusters, which might be occurring. As a result of the meeting the infection control ward nurses are attending every month, there is a chance of contamination occurring. This would be expected to result in overall increases in compliance over time, but might lead to smaller differences between pre- and post-intervention periods in implementing wards.

A final limitation was the difficulty in the wards self-reporting of the specific intervention measures they had taken, which was consistently poor.

Future analysis of the data collected in this study needs to explore factors associated with positive and negative outcomes at the ward level. Qualitative methods need to consider how successful factors in the ward-based culture act to improve hand hygiene and also consider additional interventions (goal-setting, incentives) and seek to engage higher-level decision-makers in overcoming institutional inertia. The association between hand hygiene compliance and the rate of HCAIs needs to be explored as well.
5.5 Conclusions

In conclusion, this study has evaluated an intervention that implemented the WHO Multimodal Hand Hygiene Improvement Strategy outside a high income country. The results show a small positive affect overall, though with much larger effects in some wards. They also provide information on the feasibility and difficulties of implementing the WHO strategy.

The findings from this study are intended to be generalizable to other resource-constrained hospitals in Thailand and elsewhere. Applying the WHO strategy by making ward-specific plans with involvement of the ward staff under the supervision of the infection control team led to improvements in hand hygiene behavior, though the size of these improvements was small and unlikely to translate into substantial clinical benefit. This study should provide outcomes that can inform further improvements in hand hygiene improvement strategies.
Chapter 6

Discussion and conclusions

Chapter 3-5 provided the main findings, as well as discussions and conclusions for each study in turn. This chapter summarizes the key findings, the strengths and limitation of this thesis and the overall conclusions. Future research recommendations are also considered.

6.1 Substantive discussion

Key results from the analysis of retrospective data in chapter 3 were the findings that there is a high and increasing incidence of hospital-acquired bacteraemia (HAB) and healthcare-associated bacteraemia (HCAB) in provincial hospitals in northeast Thailand, an increasing proportion of extended-spectrum beta-lactamases-producing (ESBL-producing) isolates, and very high associated mortality. This study also showed that nosocomial infection is an increasing and important problem in northeast Thailand. The total number of deaths associated with HAB and HCAB in 2010 in the study (n= 634) were much higher than the total number of reported deaths due to important notifiable diseases such as dengue hemorrhagic fever (n= 139), influenza (n= 126), and leptospirosis (n= 43) during the same period countrywide.

A key strength of this work was the use of long time series and linking of multiple routinely available databases to get a better picture of the epidemiology of HAB and HCAB in northeast Thailand. A limitation of this study is that more complete clinical data were not available. As data on process surveillance were not available, the reasons for the increased incidence of HAB could not be systematically assessed.
Although monitoring of nosocomial infection in developing countries is hampered by incomplete routine notification, this study has shown that careful evaluation of readily available routinely collected databases can provide valuable information on the incidence and trends of HAB and HCAB. The methodology used could be applied to other geographical areas where microbiological facilities are available to provide a more comprehensive global picture of the importance of nosocomial infection as a cause of death. These estimates reinforce the need for improved surveillance and prevention of nosocomial infection in similar settings.

There are a number of ways that future research could follow on from this work. In some cases, information on nosocomial infection in developing countries can be obtained by integrating readily available databases. Linking routine clinical and laboratory databases can lead to a better understanding of the burden of healthcare-associated infection (HCAI) and help infection-control practitioners better target their efforts to reduce the incidence of HCAI and associated mortality.

Although the study data showed that, in general, patients with HAB and HCAB stayed in the hospital longer than those without, the analysis did not take account of the high mortality associated with HAB and HCAB. The length of stay would be further extended if mortality in patients with HAB and HCAB could be reduced. Additional costs and extra length of stay attributable to HAB and HCAB will be further evaluated in the future using health economic models.

The qualitative and quantitative work described in Chapter 4, evaluating knowledge, beliefs and practice about hand hygiene in healthcare workers represents one of the first reports applying a theoretical domain framework to identify systematically the barriers or enablers that may affect hand hygiene behaviour of HCWs in a resource limited setting. The results showed clear differences across theoretical domains at the individual level, suggesting some explanations for implementation difficulties. This study used triangulation to identify the factors associated with hand hygiene compliance, and applied a systematic approach to explore the factors associated with hand hygiene behaviour, linking these to behaviour change techniques in the intervention phase.
Limitations of this included, first, the fact that allocation of certain items to domains was not always clear. Second, some domains might have overlapping meanings that could affect the results. One example of such potential overlap is the domain social/professional role and identity and the domain social influences.

The results from this part of the thesis are important because intervention development can potentially benefit from identifying relevant domains as part of the process. When designing interventions to improve hand hygiene, target domains should not only be selected but also the relevance of each domain to behaviour change should be considered as well. Future research is needed to evaluate how these domains relate to behaviours targeted in the promotion of hand hygiene, and how various interventions can change these behaviours.

The key findings of the trial described in Chapter 5 were that a multimodal hand hygiene improvement intervention, designed using a stepped wedge cluster randomized controlled trial with active engagement of ward staff in designing the action plan to induce behaviour change at the ward level, produced a small improvement in hand hygiene in both intention-to-intervene and per-protocol analyses. The reasons for the quite disappointing levels of improvement might come from the several difficulties of implementation, including factors at the ward and hospital level. Some evidence of clinically significant improvements in individual wards was, however, found. This could be related to wards having greater success in changing the ward-based culture or high-level co-operation in the ward from all ward staff.

A principle strength of the study is the strong design to evaluate the impact of the WHO strategy by using the stepped wedge design. This design allows each ward to compare their own compliance at multiple time points, before and after the intervention. The study’s main limitation was that the intervention was more difficult to implement than anticipated despite high level support for the intervention in the hospital.
The results from this study are important because, to our knowledge, this is the first randomized controlled trial applying the WHO hand hygiene intervention outside high income countries. While the improvements were small, and probably of limited overall clinical significance, the study establishes the feasibility of applying the WHO strategy to promote hand hygiene in resource limited settings.

Though the overall improvements in hand hygiene were disappointing, studies such as this one which do not achieve substantial improvement are important in helping identify limitations of existing approaches to hospital hygiene, identifying obstacles to improvement, and in suggesting ways in which such obstacles may be overcome. It is therefore important to consider possible reasons that explain why only small improvements in hand hygiene compliance were seen in this study. There are two aspects to this problem.

Firstly, factors relating to the delivery of the intervention:

(1) Delays in the implementation of the intervention. Only 16 wards from 58 delivered the intervention at the time specified in the protocol (the others delivered the intervention at a later time). This resulted in reduced time to completely implement all five multimodal components of the WHO intervention. In fact, only 5 wards completely implemented all five components of the intervention.

(2) Absence of system to monitor the interventions. While the ICT had been requested to provide routine monthly reports about interventions in place in different wards, in practice this rarely happened, and there were no systems in place to provide incentives to the ICT team to monitor intervention delivery.

Secondly, hospital factors relating to the level of receptiveness to the intervention:
The high workload of ward staff, with bed occupancy over 100% during the study period (range from 115% to 120%), and number of beds for admissions increasing from 1,200 beds in 2013 to 1,400 beds in 2015 (without an increase in the number of wards), may have affected receptiveness to the intervention amongst hospital staff. At this hospital general wards, such as medical and surgical wards, have a low ratio of nurses to patients (approximately 1 nurse: 10 patients). Numerous studies have previously reported that high staff workload is associated with reduced hand hygiene compliance.

The high workload of the ICT. At the study hospital the ICT were responsible for 70 in-patient wards, 12 out-patient wards, and 8 operation rooms. The ICT has four full-time infection control nurses (1 ICN: 300 beds). When comparing this ratio to other studies, the Study on the Efficacy of Nosocomial Infection Control (SENIC Project) recommended a ratio of one infection preventionist (IP) to 250 acute care beds in 1980\(^{(199)}\) (only slightly below the ratio in our study). In contrast, in the United States, it is reported that there is an average of 1.2 infection preventionists (IPs) per 100 beds.\(^{(200)}\)

Lack of prioritization for hand hygiene amongst hospital staff and the ICT, and lack of priority guidelines for infection prevention and control amongst all levels of hospital staff may be an important factor in the disappointing results. A major concern of the ICT was to investigate and attempt to control perceived outbreaks (i.e. clusters of similar infections), and these activities may have taken precedence over efforts to increase basic hygiene. This suggests that recommendations from the World Health Organization that good hygiene should be at the heart of infection control and the first priority for controlling health-care associated infections had either not been effectively communicated to healthcare workers within the hospital in general and the ICT in particular or were not believed. This suggests that clear guidelines for prioritizing infection prevention control activities are needed, alongside effective interventions to communicate such guidelines to relevant staff and to ensure their implementation.\(^{(69)}\)

Future analysis of the data collected in this study will be able to explore factors associated with positive and negative outcomes at the ward level. Qualitative methods need to consider how
successful factors in the ward-based culture act to improve hand hygiene and also consider additional interventions (e.g. goal-setting, incentives) and seek to engage higher-level decision-makers in overcoming institutional inertia. The association between hand hygiene compliance and the rate of HCAIs needs to be explored as well.

6.2 Implications of the research findings

The findings from chapter 3 based on linking of clinical databases, such as microbiological and admission data highlights the value of this approach for understanding the changing burden of hospital-acquired infection and multiple drug resistance (MDR) in a resource limited setting.

Such an approach is likely to be valuable in other countries as well, and could be expanded to study the epidemiology and burden of multidrug-resistant bacterial more widely. This approach also provides important information for infection control programmes as it shows the current epidemiological picture and trends and can help guide the generation of future policies for infection control. This surveillance of HCAI underpins infection control activities and efforts to reduce the burden of HCAI.

The findings from chapter 4 provide important information that can lead to a better understanding of factors associated with non-compliance in hand hygiene behaviour. This information is important for designing and implementing interventions because it both helps to establish a baseline (of knowledge, compliance etc.) but also reveals specific problems that need to be addressed. This can help each setting to generate an action plan to promote hand hygiene. All fourteen domains of the theoretical domain framework were addressed and their effect on hand hygiene behavior considered. It is not only the pre-intervention phase that needs to identify the barriers to better hand hygiene behaviour, but also, in the intervention phase, behaviour change techniques could be applied to increase the chance of success. Other studies have already demonstrated that this approach can
work, applying the behaviour change technique during the intervention and leading to real improvements.\textsuperscript{100} The qualitative work also helped to highlight the fact that hand hygiene consumes a lot of time this may be a key barrier for better hand hygiene behaviour in this study. Several studies have demonstrated that alcohol-based handrub (ABHR) is much more effective than handwashing at decontaminating hands and killing bacteria, as well as requiring less time using than handwashing with soap and water. To address the time concern, Reilly \textit{et al.} conducted an RCT to evaluate the microbiologic effectiveness of the World Health Organization’s 6-step (WHO’s 6-step) and the Centers for Disease Control and Prevention’s 3-step (CDC’s 3-step) hand hygiene techniques using ABHR. While the results showed that the two methods are both effective to reduce the bacteria count,\textsuperscript{80} it also provided the first evidence in an RCT that the 6-step technique is superior, suggesting that international guidance documents should consider this evidence, as should healthcare organizations still using the 3-step technique in practice.\textsuperscript{80}

In chapter 5, by promoting hand hygiene compliance by applying the WHO multimodal strategy with custom ward-based implementation, several difficulties to implement the intervention were found. In particular, as in previous RCTs in high income countries,\textsuperscript{108} an important reason for this may be due to lack of concern with hand hygiene as a hospital priority and consequent lack support from the hospital administrators. However, some ward with high co-operation and good improvement were found. Ward-based promotion of hand hygiene has the potential to increase chances of success because local ward-specific challenges and opportunities can be addressed. Support from administrative staff and the infection control team are continuously needed in the process of promoting hand hygiene.\textsuperscript{204} The linkage between improving hand hygiene and the reduction of HCAI is another reason for the need to raise the priority of hand hygiene in healthcare settings. The scientific evidence generated should also support decision making for hand hygiene interventions.\textsuperscript{81, 205, 206}
6.3 Limitations of this thesis

There are several important limitations in this thesis.

- Firstly, we cannot easily compare benchmarks of HAB and HCAB with other settings in Thailand due to lack of clinical data, and we do not currently have data to look at rates of HAB and HCAB after 2010.

- Secondly, this study cannot assess the relationship between improving hand hygiene and HCAIs. This is because of lack of statistical power and the small effect of the intervention in improving hand hygiene.

- Thirdly, there might be contamination between the wards that have received the intervention and those that haven’t, diluting the measurable intervention effect. Because all infection control ward nurses have a routine meeting every month, information from wards that have received the intervention might be shared with wards that haven’t. This would be expected to lead to a reduced difference in outcomes between intervention and control groups.

- Finally, the original intention was that the ICT would be responsible for delivering the intervention to the ward staff with the intervention team including one ICT member, one member of research staff, and one ID physician. This is because the aim was to provide a generalisable intervention at minimal additional cost (and therefore no additional resources were supplied for implementing it, considering it as part of the expected duties of the infection control team). In practice, it was only in the first six months of the intervention period that the intervention was delivered by ICT. After this period the majority of the intervention was delivered jointly by research staff and the ID physician, because the ICT is fully occupied with routine hospital work.
### 6.4 Strengths of this thesis

Key strengths of the thesis include the use of combined data sources for enhanced epidemiological surveillance, application of a systematic theory and triangulation to explore the determinants of hand hygiene behavior, and the use a strong design (a randomized control trial) to assess the impact of hand hygiene interventions at both hospital and ward level.

### 6.5 Future research directions

Further analysis need to be performed to (1) determine the factors associated with any decline/increase hand hygiene compliance (day, seasonal, individual); (2) to identify the association between hand hygiene compliance and HCAI; (3) to assess the short and longer-term success of strategies to improve hand hygiene compliance and to determine whether a sustained increase in hand hygiene compliance can reduce the burden of healthcare-associated infections. Modeling could also be applied to determine factors associated with any decline/increase in compliance to reduce of healthcare-associated infection. Both qualitative research and model-based analysis of time series hand hygiene data should also be performed to identify appropriate timing for re-booting the intervention program.

In addition to recognition of the research findings, establishing methods and models for further work in LMIC settings are important outputs. The mixed method approaches employed to gain a deeper understanding of hand hygiene behaviour are increasingly being recognised as a valuable tool for helping to understand obstacles to improvements that need to be overcome. Future research could go on to use such methods to better understand how the ICT chooses to prioritize decisions with the aim of developing interventions to help them make better decisions. The burden study illustrated the great value of linking different databases, and illustrated feasible methods to capture the number of hospital-acquired infection, which have clear relevance for other settings. The intervention study was innovative both in the use of the methodologically strong stepped-wedge design and the
participatory approach to intervention development. While this was associated with good improvements in hand hygiene behaviour in some wards, and these wards can be used as role models for future interventions (7 wards from 58 wards), more work needs to be done to explore how such positive outcomes could be extended to other wards. It seems likely that having systems in place to monitor and feedback intervention deployment may represent an important aspect of future work, given the low take-up of interventions. Even though this study didn't achieve substantial improvements throughout the whole hospital, examples where the intervention did appear to work may provide insights of relevance for future work. For example, one ward saw a three-fold improvement in hand hygiene, and ward staff showed evidence of working well as a team work and feeling ownership in the interventions to promote hand hygiene. In this ward, for each type of HCW there was a key leader in the ward team taking responsibility for the design and evaluation of the intervention. The benefits of such feelings of ownership have been referred to as the "IKEA effect" concept, which has previously been reported to provide good results in another study aimed at promoting antimicrobial stewardship in hospitals. [207]

6.6 Conclusions

This thesis highlights the importance of addressing the burden of HCAIs in northeast Thailand. Almost certainly the results and the methods used have wider applicability and linking available databases in other settings is likely to lead to better estimates of the burden of HCAI. It also points to ways in which HCAI can be prevented by the promotion of proper hand hygiene practice by HCWs; equally importantly, it highlights the challenges in doing this.

The compliance with recommended hand hygiene guidelines amongst healthcare workers (HCWs) was low in the study hospital, and is probably still much too low worldwide, including in Thailand. A better understanding of the factors associated with non-compliance by applying behaviour theories can play an important role in solving this problem and designing better interventions to promote hand
hygiene. It is not only the individual factors that influence hand hygiene behaviour but the social context (intrapersonal, community interactions) that needs to be systematically identified.

In this study it was found that the impact of the WHO multimodal strategy was low, probably in part due to problems in fully implementing the strategy as planned. New approaches are needed to address these implementation challenges. For example, goal-setting, better support from peers (including local hand hygiene “champions”) and from administrators and the infection control team, which should act as supporter, supervisor, and monitor through the intervention. These could all play a role to ensure hand hygiene has a high priority and is performed routinely as part of standard care.
References


92. Lipworth, W., N. Taylor, and J. Braithwaite, *Can the theoretical domains framework account for the implementation of clinical quality interventions?* BMC Health Serv Res, 2013. 13: p. 530.


Appendix A

Chapter 2 Supplementary
A.1: Factors influencing adherence to recommended hand hygiene practices reported by the WHO Guidelines on Hand Hygiene in Health Care[78]

<table>
<thead>
<tr>
<th>Observed risk factors for poor adherence to recommended hand hygiene practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctor status (rather than a nurse)</td>
</tr>
<tr>
<td>Nursing assistant status (rather than a nurse)</td>
</tr>
<tr>
<td>Physiotherapist</td>
</tr>
<tr>
<td>Technician</td>
</tr>
<tr>
<td>Male gender</td>
</tr>
<tr>
<td>Working in intensive care</td>
</tr>
<tr>
<td>Working in surgical care unit</td>
</tr>
<tr>
<td>Working in emergency care</td>
</tr>
<tr>
<td>Working during the week (vs. week-end)</td>
</tr>
<tr>
<td>Wearing gowns/gloves</td>
</tr>
<tr>
<td>Before contact with patient environment</td>
</tr>
<tr>
<td>After contact with patient environment e.g. equipment</td>
</tr>
<tr>
<td>Caring for patients aged less than 65 years’ old</td>
</tr>
<tr>
<td>Patient care in non-isolation room</td>
</tr>
<tr>
<td>Duration of contact with patient (&lt; or equal to 2 minutes)</td>
</tr>
<tr>
<td>Interruption in patient-care activities</td>
</tr>
<tr>
<td>Automated sink</td>
</tr>
<tr>
<td>Activities with high risk of cross-transmission</td>
</tr>
<tr>
<td>Understaffing/overcrowding</td>
</tr>
<tr>
<td>High number of opportunities for hand hygiene per hour of patient care</td>
</tr>
</tbody>
</table>
### A.1: Factors influencing adherence to recommended hand hygiene practices reported by the WHO Guidelines on Hand Hygiene in Health Care\(^{[78]}\) (cont.)

<table>
<thead>
<tr>
<th>Self-reported factors for poor adherence with hand hygiene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handwashing agents cause irritation and dryness</td>
</tr>
<tr>
<td>Sinks are inconveniently located/shortage of sinks</td>
</tr>
<tr>
<td>Lack of soap, paper, towel</td>
</tr>
<tr>
<td>Often too busy/insufficient time</td>
</tr>
<tr>
<td>Patient needs take priority</td>
</tr>
<tr>
<td>Hand hygiene interferes with HCW-patient relation</td>
</tr>
<tr>
<td>Low risk of acquiring infection from patients</td>
</tr>
<tr>
<td>Wearing of gloves/beliefs that glove use obviates the need for hand hygiene</td>
</tr>
<tr>
<td>Lack of knowledge of guidelines/protocols</td>
</tr>
<tr>
<td>Lack of knowledge, experience and education</td>
</tr>
<tr>
<td>Lack of rewards/encouragement</td>
</tr>
<tr>
<td>Lack of role model from colleagues or superiors</td>
</tr>
<tr>
<td>Not thinking about it/forgetfulness</td>
</tr>
<tr>
<td>Scepticism about the value of hand hygiene</td>
</tr>
<tr>
<td>Disagreement with the recommendations</td>
</tr>
<tr>
<td>Lack of scientific information of definitive impact of improved hand hygiene on HCAI</td>
</tr>
</tbody>
</table>

### Additional perceived barriers to appropriate hand hygiene

| Lack of active participation in hand hygiene promotion at individual or institutional level |
| Lack of institutional priority for hand hygiene                                                          |
| Lack of administrative sanction of non-compliers/rewarding of compliers                                  |
| Lack of institutional safety climate/culture of personal accountability of HCWs to perform hand hygiene |
Appendix B

Chapter 3 Supplementary
“โครงการวิจัยแบบย้อนหลังและตัดช่วง เพื่อศึกษาเกี่ยวกับการแพร่กระจาย ของโรคติดเชื้อแบคทีเรียในภาคตะวันออกเฉียงเหนือของประเทศไทย”

“A retrospective cross-sectional study to define the true incidence and mortality rate of bacterial infection in northeast of Thailand”

แถลงการณ์

คณะกรรมการจิตยานมหาราช

สถาบันพัฒนาการคุ้มครองการวิจัยในมนุษย์

โครงการวิจัย โครงการวิจัยแบบย้อนหลังและตัดช่วง เพื่อศึกษาเกี่ยวกับการแพร่กระจายของโรคติดเชื้อแบคทีเรียในภาคตะวันออกเฉียงเหนือของประเทศไทย ฉบับที่ 1.1 วันที่ 30 ธันวาคม 2554 หน้า 1/34
### List of participating hospitals

<table>
<thead>
<tr>
<th>Names of participating hospitals</th>
<th>Directors of the hospitals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Buriram hospital</td>
<td>Chalit Thongprayoon</td>
</tr>
<tr>
<td>2. Chaiyaphum hospital</td>
<td>Sompong Charoenwat</td>
</tr>
<tr>
<td>3. Loei hospital</td>
<td>Pramoth Boonjian</td>
</tr>
<tr>
<td>4. Mahasarakham hospital</td>
<td>Sunthorn Yontrakul</td>
</tr>
<tr>
<td>5. Nakhon Phanom hospital</td>
<td>Somkid Suriyalert</td>
</tr>
<tr>
<td>6. Nong Khai hospital</td>
<td>Kittisak Danwiboon</td>
</tr>
<tr>
<td>7. Sisaket hospital</td>
<td>Udom Petpuwadee</td>
</tr>
<tr>
<td>8. Ubon Ratchathani hospital</td>
<td>Manas Kanoksil</td>
</tr>
<tr>
<td>9. Udon Thani hospital</td>
<td>Pichart Dolchalermyuttana</td>
</tr>
<tr>
<td>10. Yasothorn hospital</td>
<td>Charan Thongthap</td>
</tr>
</tbody>
</table>
B.3: Location of participating hospitals

These were situated in: (1) Loei, (2) Udon Thani, (3) Nong Khai, (4) Nakhon Phanom, (5) Chaiyaphum, (6) Mahasarakarm, (7) Yasothon, (8) Buriram, (9) Sisaket, and (10) Ubon Ratchathani
B.4: Trend in hospital-acquired bacteraemia (HAB) (top panel) and healthcare-associated bacteraemia (HCAB) (bottom panel) in ten provincial hospitals in Thailand.
### B.5: Top five most common isolates causing primary episode of hospital-acquired bacteraemia (HAB) and healthcare-associated bacteraemia (HCAB) by year in northeast Thailand between 2004 and 2010

<table>
<thead>
<tr>
<th>Year</th>
<th>HAB</th>
<th>HCAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004 (%)</td>
<td><strong>Acinetobacter spp (20.3%)</strong></td>
<td><strong>Escherichia coli (27.9%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Escherichia coli (14.2%)</strong></td>
<td><strong>Staphylococcus aureus (15.1%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Klebsiella pneumoniae (12.3%)</strong></td>
<td><strong>Pseudomonas spp (12.8%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Staphylococcus aureus (12.3%)</strong></td>
<td><strong>Klebsiella pneumoniae (9.3%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Enterobacter spp (8.5%)</strong></td>
<td><strong>Acinetobacter spp (5.8%)</strong></td>
</tr>
<tr>
<td>2005 (%)</td>
<td><strong>Pseudomonas spp (14.0%)</strong></td>
<td><strong>Escherichia coli (24.0%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Acinetobacter spp (13.4%)</strong></td>
<td><strong>Pseudomonas spp (20.8%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Staphylococcus aureus (12.0%)</strong></td>
<td><strong>Staphylococcus aureus (14.4%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Escherichia coli (11.6%)</strong></td>
<td><strong>Klebsiella pneumoniae (8.8%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Klebsiella spp (11.3%)</strong></td>
<td><strong>Klebsiella spp (4.8%)</strong></td>
</tr>
<tr>
<td>2006 (%)</td>
<td><strong>Acinetobacter spp (15.1%)</strong></td>
<td><strong>Escherichia coli (27.4%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Staphylococcus aureus (14.7%)</strong></td>
<td><strong>Staphylococcus aureus (13.4%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Klebsiella pneumoniae (14.3%)</strong></td>
<td><strong>Pseudomonas spp (10.8%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Escherichia coli (12.0%)</strong></td>
<td><strong>Non-typhoidal Salmonella (8.9%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Pseudomonas spp (10.4%)</strong></td>
<td><strong>Klebsiella pneumoniae (6.4%)</strong></td>
</tr>
<tr>
<td>2007 (%)</td>
<td><strong>Acinetobacter spp (13.1%)</strong></td>
<td><strong>Escherichia coli (24.3%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Staphylococcus aureus (12.8%)</strong></td>
<td><strong>Staphylococcus aureus (12.5%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Pseudomonas spp (12.6%)</strong></td>
<td><strong>Klebsiella pneumoniae (9.6%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Escherichia coli (11.8%)</strong></td>
<td><strong>Polymicrobial infections (8.1%)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Klebsiella pneumoniae (11.8%)</strong></td>
<td><strong>Pseudomonas spp (7.7%)</strong></td>
</tr>
</tbody>
</table>
B.5: Top five most common isolates causing primary episode of hospital-acquired bacteraemia (HAB) and healthcare-associated bacteraemia (HCAB) by year in northeast Thailand between 2004 and 2010 (cont.)

<table>
<thead>
<tr>
<th>Year</th>
<th>HAB</th>
<th>HCAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008 (%)</td>
<td><em>Klebsiella pneumoniae</em> (17.3%)</td>
<td><em>Escherichia coli</em> (27.6%)</td>
</tr>
<tr>
<td></td>
<td><em>Acinetobacter</em> spp (15.6%)</td>
<td>Staphylococcus aureus (18.9%)</td>
</tr>
<tr>
<td></td>
<td><em>Staphylococcus aureus</em> (15.2%)</td>
<td><em>Klebsiella pneumoniae</em> (11.7%)</td>
</tr>
<tr>
<td></td>
<td><em>Escherichia coli</em> (14.4%)</td>
<td>Non-typhoidal <em>Salmonella</em> (6.0%)</td>
</tr>
<tr>
<td></td>
<td><em>Pseudomonas</em> spp (8.6%)</td>
<td><em>Pseudomonas</em> spp (6.0%)</td>
</tr>
<tr>
<td>2009 (%)</td>
<td><em>Acinetobacter</em> spp (19.4%)</td>
<td><em>Escherichia coli</em> (27.7%)</td>
</tr>
<tr>
<td></td>
<td><em>Staphylococcus aureus</em> (14.8%)</td>
<td><em>Staphylococcus aureus</em> (16.1%)</td>
</tr>
<tr>
<td></td>
<td><em>Klebsiella pneumoniae</em> (13.2%)</td>
<td><em>Klebsiella pneumoniae</em> (7.8%)</td>
</tr>
<tr>
<td></td>
<td><em>Escherichia coli</em> (12.5%)</td>
<td><em>Pseudomonas</em> spp (7.4%)</td>
</tr>
<tr>
<td></td>
<td><em>Pseudomonas</em> spp (8.7%)</td>
<td><em>Acinetobacter</em> spp (5.9%)</td>
</tr>
<tr>
<td>2010 (%)</td>
<td><em>Acinetobacter</em> spp (15.0%)</td>
<td><em>Escherichia coli</em> (25.1%)</td>
</tr>
<tr>
<td></td>
<td><em>Klebsiella pneumoniae</em> (14.6%)</td>
<td><em>Staphylococcus aureus</em> (13.4%)</td>
</tr>
<tr>
<td></td>
<td><em>Staphylococcus aureus</em> (13.4%)</td>
<td><em>Pseudomonas</em> spp (11.2%)</td>
</tr>
<tr>
<td></td>
<td><em>Pseudomonas</em> spp (12.3%)</td>
<td><em>Klebsiella pneumoniae</em> (11.0%)</td>
</tr>
<tr>
<td></td>
<td><em>Escherichia coli</em> (12.2%)</td>
<td><em>Acinetobacter</em> spp (6.4%)</td>
</tr>
</tbody>
</table>
B.6: Top five most common isolates causing primary episode of hospital-acquired bacteraemia (HAB) and of healthcare-associated bacteraemia (HCAB) by provincial hospital in northeast Thailand between 2004 and 2010

<table>
<thead>
<tr>
<th>Hospital</th>
<th>HAB</th>
<th>HCAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital A (%)</td>
<td>Staphylococcus aureus (19.3%)</td>
<td>Escherichia coli (29.7%)</td>
</tr>
<tr>
<td></td>
<td>Acinetobacter spp (17.5%)</td>
<td>Klebsiella pneumoniae (12.5%)</td>
</tr>
<tr>
<td></td>
<td>Pseudomonas spp (14.0%)</td>
<td>Pseudomonas spp (9.4%)</td>
</tr>
<tr>
<td></td>
<td>Escherichia coli (8.8%)</td>
<td>Polymicrobial infections (7.8%)</td>
</tr>
<tr>
<td></td>
<td>Klebsiella pneumoniae (5.3%)</td>
<td>Other Gram negatives (6.3%)</td>
</tr>
<tr>
<td>Hospital B (%)</td>
<td>Staphylococcus aureus (20.0%)</td>
<td>Escherichia coli (28.7%)</td>
</tr>
<tr>
<td></td>
<td>Acinetobacter spp (15.0%)</td>
<td>Staphylococcus aureus (21.8%)</td>
</tr>
<tr>
<td></td>
<td>Enterococcus spp (15.0%)</td>
<td>Klebsiella pneumoniae (8.1%)</td>
</tr>
<tr>
<td></td>
<td>Escherichia coli (11.3%)</td>
<td>Pseudomonas spp (8.1%)</td>
</tr>
<tr>
<td></td>
<td>Klebsiella pneumoniae (8.8%)</td>
<td>Enterococcus spp (6.9%)</td>
</tr>
<tr>
<td>Hospital C (%)</td>
<td>Escherichia coli (14.8%)</td>
<td>Escherichia coli (28.8%)</td>
</tr>
<tr>
<td></td>
<td>Unspecified Gram positives (12.4%)</td>
<td>Unspecified Gram positives (15.6%)</td>
</tr>
<tr>
<td></td>
<td>Klebsiella pneumoniae (9.9%)</td>
<td>Klebsiella pneumoniae (10.2%)</td>
</tr>
<tr>
<td></td>
<td>Acinetobacter spp (7.4%)</td>
<td>Polymicrobial infections (9.3%)</td>
</tr>
<tr>
<td></td>
<td>Group D streptococcus (7.4%)</td>
<td>Staphylococcus aureus (7.6%)</td>
</tr>
<tr>
<td>Hospital D (%)</td>
<td>Staphylococcus aureus (16.7%)</td>
<td>Escherichia coli (32.7%)</td>
</tr>
<tr>
<td></td>
<td>Candida spp (16.7%)</td>
<td>Staphylococcus aureus (23.1%)</td>
</tr>
<tr>
<td></td>
<td>Pseudomonas spp (12.5%)</td>
<td>Klebsiella spp (11.5%)</td>
</tr>
<tr>
<td></td>
<td>Escherichia coli (8.3%)</td>
<td>Non-typhoidal Salmonella (9.6%)</td>
</tr>
<tr>
<td></td>
<td>Klebsiella spp (8.3%)</td>
<td>Streptococcus pneumoniae (7.7%)</td>
</tr>
</tbody>
</table>
B.6: Top five most common isolates causing primary episode of hospital-acquired bacteraemia (HAB) and of healthcare-associated bacteraemia (HCAB) by provincial hospital in northeast Thailand between 2004 and 2010 (cont.)

<table>
<thead>
<tr>
<th>Hospital</th>
<th>HAB</th>
<th>HCAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital E (%)</td>
<td>Acinetobacter spp (22.2%)</td>
<td>Escherichia coli (36.4%)</td>
</tr>
<tr>
<td></td>
<td>Unspecified Gram positives (13.9%)</td>
<td>Unspecified Gram positives (18.2%)</td>
</tr>
<tr>
<td></td>
<td>Staphylococcus aureus (12.0%)</td>
<td>Enterobacter spp (9.1%)</td>
</tr>
<tr>
<td></td>
<td>Pseudomonas spp (9.3%)</td>
<td>Staphylococcus aureus (7.8%)</td>
</tr>
<tr>
<td></td>
<td>Escherichia coli (8.3%)</td>
<td>Klebsiella pneumoniae (5.2%)</td>
</tr>
<tr>
<td>Hospital F (%)</td>
<td>Pseudomonas spp (18.6%)</td>
<td>Escherichia coli (27.1%)</td>
</tr>
<tr>
<td></td>
<td>Escherichia coli (17.1%)</td>
<td>Staphylococcus aureus (16.0%)</td>
</tr>
<tr>
<td></td>
<td>Staphylococcus aureus (12.6%)</td>
<td>Pseudomonas spp (15.7%)</td>
</tr>
<tr>
<td></td>
<td>Acinetobacter spp (11.8%)</td>
<td>Klebsiella pneumoniae (8.5%)</td>
</tr>
<tr>
<td></td>
<td>Klebsiella spp (10.6%)</td>
<td>Klebsiella spp (6.1%)</td>
</tr>
<tr>
<td>Hospital G (%)</td>
<td>Klebsiella pneumoniae (20.7%)</td>
<td>Escherichia coli (30.0%)</td>
</tr>
<tr>
<td></td>
<td>Staphylococcus aureus (16.7%)</td>
<td>Staphylococcus aureus (9.2%)</td>
</tr>
<tr>
<td></td>
<td>Escherichia coli (12.6%)</td>
<td>Non-typhoidal Salmonella (8.1%)</td>
</tr>
<tr>
<td></td>
<td>Acinetobacter spp (11.9%)</td>
<td>Klebsiella pneumoniae (8.1%)</td>
</tr>
<tr>
<td></td>
<td>Enterococcus spp (5.6%)</td>
<td>Pseudomonas spp (6.5%)</td>
</tr>
<tr>
<td>Hospital H (%)</td>
<td>Acinetobacter spp (18.5%)</td>
<td>Escherichia coli (16.4%)</td>
</tr>
<tr>
<td></td>
<td>Klebsiella pneumoniae (15.1%)</td>
<td>Achromobacter spp (14.8%)</td>
</tr>
<tr>
<td></td>
<td>Escherichia coli (14.3%)</td>
<td>Klebsiella pneumoniae (13.1%)</td>
</tr>
<tr>
<td></td>
<td>Staphylococcus aureus (10.1%)</td>
<td>Acinetobacter spp (13.1%)</td>
</tr>
<tr>
<td></td>
<td>Enterococcus spp (9.2%)</td>
<td>Staphylococcus aureus (12.3%)</td>
</tr>
</tbody>
</table>
### B.6: Top five most common isolates causing primary episode of hospital-acquired bacteraemia (HAB) and of healthcare-associated bacteraemia (HCAB) by provincial hospital in northeast Thailand between 2004 and 2010 (cont.)

<table>
<thead>
<tr>
<th>Hospital</th>
<th>HAB</th>
<th>HCAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital I (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Klebsiella pneumoniae</em> (19.3%)</td>
<td><em>Escherichia coli</em> (28.6%)</td>
</tr>
<tr>
<td></td>
<td><em>Escherichia coli</em> (13.7%)</td>
<td><em>Staphylococcus aureus</em> (10.9%)</td>
</tr>
<tr>
<td></td>
<td><em>Staphylococcus aureus</em> (12.5%)</td>
<td><em>Klebsiella pneumoniae</em> (10.5%)</td>
</tr>
<tr>
<td></td>
<td><em>Acinetobacter spp</em> (10.3%)</td>
<td><em>Acinetobacter spp</em> (8.2%)</td>
</tr>
<tr>
<td></td>
<td>Candida spp (8.0%)</td>
<td>Non-typhoidal <em>Salmonella</em> (5.6%)</td>
</tr>
<tr>
<td>Hospital J (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Acinetobacter spp</em> (20.3%)</td>
<td><em>Escherichia coli</em> (23.3%)</td>
</tr>
<tr>
<td></td>
<td><em>Staphylococcus aureus</em> (14.6%)</td>
<td><em>Staphylococcus aureus</em> (16.9%)</td>
</tr>
<tr>
<td></td>
<td><em>Klebsiella pneumoniae</em> (13.5%)</td>
<td><em>Pseudomonas spp</em> (12.2%)</td>
</tr>
<tr>
<td></td>
<td><em>Pseudomonas spp</em> (11.2%)</td>
<td><em>Klebsiella pneumoniae</em> (10.6%)</td>
</tr>
<tr>
<td></td>
<td><em>Escherichia coli</em> (11.4%)</td>
<td>Non-typhoidal <em>Salmonella</em> (6.4%)</td>
</tr>
</tbody>
</table>
B.7: Proportions of ESBL-producing *E. coli*, ESBL-producing *K. pneumoniae*, and MRSA as a cause of hospital-acquired bacteraemia (HAB) over time in northeast Thailand

<table>
<thead>
<tr>
<th>Year</th>
<th>ESBL-producing <em>E. coli</em></th>
<th>ESBL-producing <em>K. pneumoniae</em></th>
<th>MRSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>10/30 (33.3%)</td>
<td>19/26 (73.1%)</td>
<td>14/26 (53.9%)</td>
</tr>
<tr>
<td>2005</td>
<td>10/34 (29.4%)</td>
<td>20/30 (66.7%)</td>
<td>21/35 (60.0%)</td>
</tr>
<tr>
<td>2006</td>
<td>10/31 (32.3%)</td>
<td>27/37 (73.0%)</td>
<td>15/38 (39.5%)</td>
</tr>
<tr>
<td>2007</td>
<td>12/43 (27.9%)</td>
<td>30/43 (69.8%)</td>
<td>16/47 (34.0%)</td>
</tr>
<tr>
<td>2008</td>
<td>34/92 (37.0%)</td>
<td>69/111 (62.2%)</td>
<td>32/97 (33.3%)</td>
</tr>
<tr>
<td>2009</td>
<td>42/105 (40.0%)</td>
<td>51/111 (46.0%)</td>
<td>34/124 (27.4%)</td>
</tr>
<tr>
<td>2010</td>
<td>51/99 (51.5%)</td>
<td>67/119 (56.3%)</td>
<td>32/109 (29.4%)</td>
</tr>
<tr>
<td>Overall</td>
<td>169/434 (38.9%)</td>
<td>283/477 (59.3%)</td>
<td>164/476 (34.5%)</td>
</tr>
</tbody>
</table>

* Chi-square test for trend

\[ P \text{ value } * \] 0.005 0.002 <0.001
B.8: Trend in overall proportion of ESBLs producing *Escherichia coli* causing hospital-acquired bacteraemia (HAB) (left panel) and causing and healthcare-associated bacteraemia (HCAB) (right panel) in provincial hospitals in Thailand.
Proportions of ESBL-producing *E. coli*, ESBL-producing *K. pneumoniae*, and MRSA as a cause of healthcare-associated bacteraemia (HCAB) over time in northeast Thailand

<table>
<thead>
<tr>
<th>Year</th>
<th>ESBL-producing <em>E. coli</em></th>
<th>ESBL-producing <em>K. pneumoniae</em></th>
<th>MRSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>5/24 (20.8%)</td>
<td>0/8 (0.0%)</td>
<td>2/13 (15.4%)</td>
</tr>
<tr>
<td>2005</td>
<td>6/30 (20.0%)</td>
<td>5/11 (45.5%)</td>
<td>3/18 (16.7%)</td>
</tr>
<tr>
<td>2006</td>
<td>3/43 (7.0%)</td>
<td>4/10 (40.0%)</td>
<td>8/21 (38.1%)</td>
</tr>
<tr>
<td>2007</td>
<td>10/66 (15.2%)</td>
<td>8/26 (30.8%)</td>
<td>5/34 (14.7%)</td>
</tr>
<tr>
<td>2008</td>
<td>45/120 (37.5%)</td>
<td>20/51 (39.2%)</td>
<td>8/56 (14.3%)</td>
</tr>
<tr>
<td>2009</td>
<td>58/146 (39.7%)</td>
<td>9/41 (22.0%)</td>
<td>20/85 (23.5%)</td>
</tr>
<tr>
<td>2010</td>
<td>48/146 (32.9%)</td>
<td>24/64 (37.5%)</td>
<td>21/78 (26.9%)</td>
</tr>
<tr>
<td>Overall</td>
<td>175/575 (30.4%)</td>
<td>70/211 (33.2%)</td>
<td>67/305 (22.0%)</td>
</tr>
</tbody>
</table>

*Chi-square test for trend

- *P value*: 
  - 0.001 for ESBL-producing *E. coli*
  - 0.557 for ESBL-producing *K. pneumoniae*
  - 0.383 for MRSA
B.10: Trend in overall proportion of ESBLs producing *Klebsiella pneumonia* causing hospital-acquired bacteraemia (HAB) (left panel) and causing and healthcare-associated bacteraemia (HCAB) (right panel) in provincial hospitals in Thailand

![Graph showing trend in overall proportion of ESBLs producing Klebsiella pneumonia causing HAB and HCAB](image)
B.11: Trend in overall proportion of methicillin resistant *Staphylococcus aureus* causing hospital-acquired bacteraemia (HAB) (left panel) and causing and healthcare-associated bacteraemia (HCAB) (right panel) in provincial hospitals in Thailand.
Appendix C

Chapter 4 Supplementary
CERTIFICATE OF ETHICAL APPROVAL
Ethics Committee of the Faculty of Tropical Medicine, Mahidol University
420/6 Ratchawithi Rd., Ratchathewee, Bangkok 10400, Thailand

This Certificate of Ethical Approval (MUTM 2010-054-01) applies to the

Project entitled: A non-interventional investigation into infection control practices, and obstacles to improvements amongst healthcare workers at a regional hospital

EC Submission No.: TMEC 10-035

with the following relevant documents:

Research proposal: English, version 2.0 dated 26 October 2010 (based on full protocol version 2.0 dated 26 October 2010)

Participant Information Sheet for Doctors, Nurses, Practical nurses, Nurse-aid:
Thai, version 2.0 dated 26 October 2010

Participant Information Sheet for Medical/Nurse students:
Thai, version 2.0 dated 26 October 2010

Participant Information Sheet for Management Team:
Thai, version 2.0 dated 26 October 2010

Questionnaires Form:
Thai, version 2.0 dated 26 October 2010

Semi-structured interviews Form:
Thai, version 2.0 dated 26 October 2010

Focus group Discussion Form:
Thai, version 2.0 dated 26 October 2010

Observation Form:
Thai, version 2.0 dated 26 October 2010

Ward Infrastructure Survey Form:
Thai, version 1.0 dated 13 July 2010
Dr D Limmathurotsakul
Department of Tropical Hygiene
Mahidol Oxford Research Unit
Faculty of Tropical Medicine
Mahidol University
Thailand

14th February 2011

Dear Dr Limmathurotsakul

Full Title of Study: A non-interventional investigation into infection control practices and obstacles to improvements amongst healthcare workers (HCWs) at a regional hospital in NE Thailand

OXTREC Reference: 08-11

The OXTREC executive team reviewed the above application

In addition to your application, the documents reviewed were:

<table>
<thead>
<tr>
<th>Documentation:</th>
<th>Version:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocol</td>
<td>V2.0</td>
<td>26.10.2010</td>
</tr>
<tr>
<td>Participant Information Sheet</td>
<td>V2.0</td>
<td>26.10.2010</td>
</tr>
<tr>
<td>Participant Consent Form</td>
<td>V1.0</td>
<td>13.07.2010</td>
</tr>
<tr>
<td>LEC approval letter</td>
<td></td>
<td>09.11.2010</td>
</tr>
</tbody>
</table>

The executive team gave approval to the study subject to a correction of the dates of the study’s duration in the participant information sheets (the translated versions give dates which we believe you have changed).

We look forward to receiving your annual/end of study report.

Yours sincerely,

Dr Richard Mayon-White

OXTREC Chair
### C.2: Theoretical Domains Framework and example questions

<table>
<thead>
<tr>
<th>Theoretical domain</th>
<th>Operational definition*</th>
<th>Sample question</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDF1: Knowledge</td>
<td>Knowledge of the rules, protocol or indications governing hand hygiene</td>
<td>Which of the following hand hygiene actions prevents transmission of germs to the health-care worker</td>
</tr>
<tr>
<td>TDF2: Skills</td>
<td>Necessary practical skills and competencies to perform hand hygiene</td>
<td>How many times on hand hygiene training</td>
</tr>
<tr>
<td>TDF3: Social/professional role and identity</td>
<td>A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting.</td>
<td>You dare not remind colleagues and doctors to wash their hands. Because medical personnel and would know how to treat it.</td>
</tr>
<tr>
<td>TDF4: Beliefs about capabilities</td>
<td>Acceptance of the truth, reality or validity about an ability, talent or facility that a person can put to constructive use, for example, self-confidence.</td>
<td>Do you think washing hands immediately after nursing caused confidence in the care of other patients next</td>
</tr>
<tr>
<td>TDF5: Optimism</td>
<td>The confidence that things will happen for the best or that desired goals will be attained, for example, optimism, pessimism.</td>
<td>% of self-reported on hand hygiene</td>
</tr>
</tbody>
</table>

*Operation definitions are adapted from Cane et al., 2012

TDF = Theoretical Domains Framework
C.2: Theoretical Domains Framework and example questions

<table>
<thead>
<tr>
<th>Theoretical domain</th>
<th>Operational definition*</th>
<th>Sample question</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDF1: Knowledge</td>
<td>Knowledge of the rules, protocol or indications governing hand hygiene</td>
<td>Which of the following hand hygiene actions prevents transmission of germs to the health-care worker</td>
</tr>
<tr>
<td>TDF2: Skills</td>
<td>Necessary practical skills and competencies to perform hand hygiene</td>
<td>How many times on hand hygiene training</td>
</tr>
<tr>
<td>TDF3: Social/professional role and identity</td>
<td>A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting.</td>
<td>You dare not remind colleagues and doctors to wash their hands. Because medical personnel and would know how to treat it.</td>
</tr>
<tr>
<td>TDF4: Beliefs about capabilities</td>
<td>Acceptance of the truth, reality or validity about an ability, talent or facility that a person can put to constructive use, for example, self-confidence.</td>
<td>Do you think washing hands immediately after nursing caused confidence in the care of other patients next</td>
</tr>
<tr>
<td>TDF5: Optimism</td>
<td>The confidence that things will happen for the best or that desired goals will be attained, for example, optimism, pessimism.</td>
<td>% of self-reported on hand hygiene</td>
</tr>
</tbody>
</table>

*Operation definitions are adapted from Cane et al., 2012

TDF = Theoretical Domains Framework
C.2: Theoretical Domains Framework and example questions (cont.)

<table>
<thead>
<tr>
<th>Theoretical domain</th>
<th>Operational definition*</th>
<th>Sample question</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDF6: Beliefs about consequences</td>
<td>Perceived consequences of hand hygiene, <em>i.e.</em>, what are the costs/benefits to patients and healthcare workers</td>
<td>Do you think nurse no need to perform hand washing after taking off gloves because it has no direct contact to patient</td>
</tr>
<tr>
<td></td>
<td>Cognitive evaluation of the consequences of hand hygiene, including transmission of microorganisms, control over the environment, and professional behaviour</td>
<td></td>
</tr>
<tr>
<td>TDF7: Reinforcement</td>
<td>Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus, for example, rewards.</td>
<td>Opened question on list of obstacle</td>
</tr>
<tr>
<td>TDF8: Intentions</td>
<td>Plans to adhere to hand hygiene recommendations in a variety of clinical situations</td>
<td>Do you think nurses should wash their hands before and after patient care</td>
</tr>
<tr>
<td>TDF9: Goals</td>
<td>Mental representations of outcomes or end states that an individual wants to achieve, for example, goal/target setting.</td>
<td>I want all staff to wash their hands before and after nursing</td>
</tr>
<tr>
<td>TDF10: Memory, attention, and decision processes</td>
<td>Forgetting to perform hand hygiene, concentration on/attention to another task, <em>i.e.</em>, being distracted by another non-urgent task, or making a conscious decision not to clean hands because another task is more urgent</td>
<td>Whether rush just need to wash their hands before providing nursing care</td>
</tr>
</tbody>
</table>

*Operation definitions are adapted from Cane et al., 2012

TDF = Theoretical Domains Framework
## Theoretical Domains Framework and example questions (cont.)

<table>
<thead>
<tr>
<th>Theoretical domain</th>
<th>Operational definition*</th>
<th>Sample question</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDF11: Environmental context and resources</td>
<td>The role of environmental factors, i.e., workload or lack of other resources in reducing the likelihood of performing hand hygiene</td>
<td>Do you think washing is something that everyone must follow? To prevent the spread of infection</td>
</tr>
<tr>
<td>TDF12: Social influences</td>
<td>The role of peers in influencing hand hygiene behaviour</td>
<td>The approval and support of the hospital. Makes you dare remind colleagues and doctors to wash their hands</td>
</tr>
<tr>
<td>TDF13: Emotion</td>
<td>Emotions that may affect hand hygiene behaviour</td>
<td>Hand washing is boring</td>
</tr>
<tr>
<td>TDF14: Behavioural regulation</td>
<td>Anything aimed at managing or changing objectively observed or measured actions, for example, self-monitoring.</td>
<td>Do you think nurse no need to perform hand washing after taking off gloves because it has no directly contact to patient</td>
</tr>
</tbody>
</table>

*Operation definitions are adapted from Cane et al., 2012

TDF = Theoretical Domains Framework
C.3: Participants of focus groups according their departments

<table>
<thead>
<tr>
<th>Type of HCWs</th>
<th>Department</th>
<th></th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Medicine</td>
<td>Surgery</td>
<td>Pediatric</td>
<td>Obstetrics and Gynecology</td>
<td></td>
</tr>
<tr>
<td>Registered nurses</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Infection control ward nurses</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Nurse-aids</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Workers</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>12</td>
<td>7</td>
<td>3</td>
<td>32</td>
</tr>
</tbody>
</table>
### C.4: Descriptive data of semi-structured interview participants (n = 5)

<table>
<thead>
<tr>
<th>Interview No.</th>
<th>Gender</th>
<th>Age (year)</th>
<th>Role type</th>
<th>Work area</th>
<th>Work status</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI1</td>
<td>Male</td>
<td>51</td>
<td>Head of infection control team</td>
<td>Physician (pediatric, infection disease)</td>
<td>Full-time</td>
</tr>
<tr>
<td>SI2</td>
<td>Female</td>
<td>47</td>
<td>Head of laboratory department</td>
<td>Lab technician</td>
<td>Full-time</td>
</tr>
<tr>
<td>SI3</td>
<td>Male</td>
<td>58</td>
<td>Head of surgical department</td>
<td>Physician (surgery)</td>
<td>Full-time</td>
</tr>
<tr>
<td>SI4</td>
<td>Male</td>
<td>59</td>
<td>Deputy director</td>
<td>Physician (surgery)</td>
<td>Full-time</td>
</tr>
<tr>
<td>SI5</td>
<td>Male</td>
<td>56</td>
<td>Head of eye-nose-throat department</td>
<td>Physician</td>
<td>Full-time</td>
</tr>
</tbody>
</table>
C.5: Summary of current knowledge of hand hygiene from participants (N = 1,582)

<table>
<thead>
<tr>
<th>Knowledge on hand hygiene</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>14.3</td>
<td>15</td>
<td>2.6</td>
<td>0</td>
<td>22</td>
<td>1,582 (100 %)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>13.8</td>
<td>14</td>
<td>3.0</td>
<td>0</td>
<td>20</td>
<td>272 (19.7 %)</td>
</tr>
<tr>
<td>Female</td>
<td>14.5</td>
<td>15</td>
<td>2.5</td>
<td>0</td>
<td>22</td>
<td>1,310 (80.3 %)</td>
</tr>
<tr>
<td>Year of working experience</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1 year</td>
<td>14.6</td>
<td>15</td>
<td>2.1</td>
<td>1</td>
<td>19</td>
<td>157 (9.3 %)</td>
</tr>
<tr>
<td>2 – 5 years</td>
<td>14.5</td>
<td>15</td>
<td>2.5</td>
<td>0</td>
<td>22</td>
<td>517 (30.5 %)</td>
</tr>
<tr>
<td>6 – 10 years</td>
<td>14.4</td>
<td>15</td>
<td>2.3</td>
<td>2</td>
<td>20</td>
<td>168 (9.9 %)</td>
</tr>
<tr>
<td>11 – 20 years</td>
<td>14.6</td>
<td>15</td>
<td>2.2</td>
<td>0</td>
<td>19</td>
<td>300 (17.7 %)</td>
</tr>
<tr>
<td>&gt; 20 years</td>
<td>13.8</td>
<td>14</td>
<td>3.2</td>
<td>0</td>
<td>20</td>
<td>381 (29.1 %)</td>
</tr>
<tr>
<td>Type of healthcare workers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physicians</td>
<td>14.5</td>
<td>14</td>
<td>2.3</td>
<td>10</td>
<td>19</td>
<td>13 (7.2 %)</td>
</tr>
<tr>
<td>Nurses</td>
<td>14.5</td>
<td>15</td>
<td>2.3</td>
<td>0</td>
<td>22</td>
<td>812 (47.8 %)</td>
</tr>
<tr>
<td>Auxiliaries</td>
<td>13.8</td>
<td>14</td>
<td>3.3</td>
<td>0</td>
<td>18</td>
<td>458 (26.9 %)</td>
</tr>
<tr>
<td>Nursing students</td>
<td>14.7</td>
<td>15</td>
<td>1.9</td>
<td>1</td>
<td>19</td>
<td>299 (18.0 %)</td>
</tr>
<tr>
<td>Ward type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICU</td>
<td>14.8</td>
<td>15</td>
<td>2.2</td>
<td>0</td>
<td>21</td>
<td>370 (21.9 %)</td>
</tr>
<tr>
<td>Non-ICU</td>
<td>14.1</td>
<td>15</td>
<td>2.7</td>
<td>0</td>
<td>20</td>
<td>778 (46.1 %)</td>
</tr>
</tbody>
</table>

N = number of respondents of total study population, SD = Standard deviation, ICU = Intensive care unit
### Summary of current knowledge of hand hygiene from participants (N = 1,582) (cont.)

<table>
<thead>
<tr>
<th>Department</th>
<th>Knowledge on hand hygiene</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Eye Ear Nose Throat</td>
<td>13.9</td>
</tr>
<tr>
<td>Obstetrics and Gynecology</td>
<td>14.2</td>
</tr>
<tr>
<td>Medicine</td>
<td>14.1</td>
</tr>
<tr>
<td>Peadiatric</td>
<td>14.4</td>
</tr>
<tr>
<td>Surgery</td>
<td>14.3</td>
</tr>
</tbody>
</table>

N = number of respondents of total study population, SD = Standard deviation, ICU = Intensive care unit
C.6: Summary of self-reporting on hand hygiene compliance from participants (n = 1,126)

<table>
<thead>
<tr>
<th>% Hand hygiene by self-reporting</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>79.2</td>
<td>80</td>
<td>18.3</td>
<td>0</td>
<td>100</td>
<td>1,126 (100 %)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>76.0</td>
<td>80</td>
<td>23.0</td>
<td>0</td>
<td>100</td>
<td>181 (16.1 %)</td>
</tr>
<tr>
<td>Female</td>
<td>79.8</td>
<td>80</td>
<td>17.2</td>
<td>0</td>
<td>100</td>
<td>945 (83.9 %)</td>
</tr>
<tr>
<td>Year of working experience</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1 year</td>
<td>80.9</td>
<td>80</td>
<td>15.4</td>
<td>0</td>
<td>100</td>
<td>132 (11.7 %)</td>
</tr>
<tr>
<td>2 – 5 years</td>
<td>79.8</td>
<td>80</td>
<td>17.8</td>
<td>0</td>
<td>100</td>
<td>379 (33.7 %)</td>
</tr>
<tr>
<td>6 – 10 years</td>
<td>80.7</td>
<td>80</td>
<td>17.1</td>
<td>0</td>
<td>100</td>
<td>116 (10.3 %)</td>
</tr>
<tr>
<td>11 – 20 years</td>
<td>77.3</td>
<td>80</td>
<td>20.6</td>
<td>0</td>
<td>100</td>
<td>213 (18.9 %)</td>
</tr>
<tr>
<td>&gt; 20 years</td>
<td>78.5</td>
<td>80</td>
<td>19.3</td>
<td>0</td>
<td>100</td>
<td>248 (22.0 %)</td>
</tr>
<tr>
<td>Type of healthcare workers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physicians</td>
<td>60.9</td>
<td>50</td>
<td>25.5</td>
<td>10</td>
<td>90</td>
<td>11 (1.1 %)</td>
</tr>
<tr>
<td>Nurses</td>
<td>80.6</td>
<td>80</td>
<td>17.8</td>
<td>0</td>
<td>100</td>
<td>589 (52.0 %)</td>
</tr>
<tr>
<td>Auxiliaries</td>
<td>75.0</td>
<td>80</td>
<td>22.0</td>
<td>0</td>
<td>100</td>
<td>269 (23.6 %)</td>
</tr>
<tr>
<td>Nursing students</td>
<td>81.3</td>
<td>80</td>
<td>12.8</td>
<td>20</td>
<td>100</td>
<td>257 (23.3 %)</td>
</tr>
<tr>
<td>Ward type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICU</td>
<td>75.0</td>
<td>80</td>
<td>24.6</td>
<td>0</td>
<td>100</td>
<td>259 (23.0 %)</td>
</tr>
<tr>
<td>Non-ICU</td>
<td>79.9</td>
<td>80</td>
<td>16.3</td>
<td>0</td>
<td>100</td>
<td>522 (46.4 %)</td>
</tr>
</tbody>
</table>

N = number of respondents of total study population, SD = Standard deviation, ICU = Intensive care unit
**C.6: Summary of self-reporting on hand hygiene compliance from participants (n = 1,126) (cont.)**

<table>
<thead>
<tr>
<th>Department</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye Ear Nose Throat</td>
<td>87.0</td>
<td>90</td>
<td>9.5</td>
<td>60</td>
<td>100</td>
<td>30 (2.7 %)</td>
</tr>
<tr>
<td>Obstetrics and Gynecology</td>
<td>80.7</td>
<td>90</td>
<td>21.5</td>
<td>0</td>
<td>100</td>
<td>132 (11.7 %)</td>
</tr>
<tr>
<td>Medicine</td>
<td>71.1</td>
<td>80</td>
<td>27.7</td>
<td>0</td>
<td>100</td>
<td>178 (15.8 %)</td>
</tr>
<tr>
<td>Peadiatric</td>
<td>81.4</td>
<td>80</td>
<td>14.3</td>
<td>40</td>
<td>100</td>
<td>120 (10.7 %)</td>
</tr>
<tr>
<td>Surgery</td>
<td>80.4</td>
<td>80</td>
<td>14.5</td>
<td>7</td>
<td>100</td>
<td>392 (24.3 %)</td>
</tr>
</tbody>
</table>

N = number of respondents of total study population, SD = Standard deviation, ICU = Intensive care unit
C.7: Summary on hand hygiene performed by all opportunities for requiring hand hygiene practices (n = 3,564)

<table>
<thead>
<tr>
<th>Hand hygiene practices</th>
<th>Not performed n (%)</th>
<th>Performed incorrectly n (%)</th>
<th>Performed correctly n (%)</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>606 (88.1 %)</td>
<td>22 (3.2 %)</td>
<td>60 (8.7 %)</td>
<td>688 (100 %)</td>
</tr>
<tr>
<td>Female</td>
<td>2,483 (86.3 %)</td>
<td>135 (4.7 %)</td>
<td>258 (9.0 %)</td>
<td>2,876 (100 %)</td>
</tr>
<tr>
<td><strong>Working years</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1 years</td>
<td>190 (83.7 %)</td>
<td>13 (5.7 %)</td>
<td>24 (10.6 %)</td>
<td>227 (100 %)</td>
</tr>
<tr>
<td>2 – 5 years</td>
<td>923 (87.9 %)</td>
<td>42 (4.0 %)</td>
<td>85 (8.1 %)</td>
<td>1,050 (100 %)</td>
</tr>
<tr>
<td>6 – 10 years</td>
<td>292 (83.9 %)</td>
<td>14 (4.0 %)</td>
<td>42 (12.1 %)</td>
<td>348 (100.0%)</td>
</tr>
<tr>
<td>11 – 20 years</td>
<td>470 (85.0 %)</td>
<td>33 (6.0 %)</td>
<td>50 (9.0 %)</td>
<td>553 (100 %)</td>
</tr>
<tr>
<td>&gt; 20 years</td>
<td>1,022 (89.4 %)</td>
<td>46 (4.0 %)</td>
<td>75 (6.6 %)</td>
<td>1,143 (100 %)</td>
</tr>
<tr>
<td><strong>Type of healthcare workers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physicians</td>
<td>288 (91.7 %)</td>
<td>12 (3.8 %)</td>
<td>14 (4.5 %)</td>
<td>314 (100 %)</td>
</tr>
<tr>
<td>Nurses</td>
<td>1,497 (83.6 %)</td>
<td>93 (5.2 %)</td>
<td>201 (11.2 %)</td>
<td>1,791 (100 %)</td>
</tr>
<tr>
<td>Auxiliaries</td>
<td>854 (88.5 %)</td>
<td>39 (4.0 %)</td>
<td>72 (7.5 %)</td>
<td>965 (100 %)</td>
</tr>
<tr>
<td>Visitors</td>
<td>184 (88.0 %)</td>
<td>11 (5.3 %)</td>
<td>14 (6.7 %)</td>
<td>209 (100 %)</td>
</tr>
<tr>
<td>Nursing students</td>
<td>166 (92.2 %)</td>
<td>1 (0.6 %)</td>
<td>13 (7.2 %)</td>
<td>180 (100 %)</td>
</tr>
<tr>
<td>Medical students</td>
<td>100 (95.2 %)</td>
<td>1 (1.0 %)</td>
<td>4 (3.8 %)</td>
<td>105 (100 %)</td>
</tr>
<tr>
<td><strong>Ward type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICU</td>
<td>1,305 (82.8 %)</td>
<td>89 (5.7 %)</td>
<td>182 (11.6 %)</td>
<td>1,576 (100 %)</td>
</tr>
<tr>
<td>Non-ICU</td>
<td>1,591 (89.9 %)</td>
<td>57 (3.2 %)</td>
<td>121 (6.8 %)</td>
<td>1,769 (100 %)</td>
</tr>
</tbody>
</table>

n = number of respondents of part of study population, SD = Standard deviation, ICU = Intensive-care unit
C.7: Summary on hand hygiene performed by all opportunities for requiring hand hygiene practices (n = 3,564)

<table>
<thead>
<tr>
<th>Department</th>
<th>Not performed n (%)</th>
<th>Performed incorrectly n (%)</th>
<th>Performed correctly n (%)</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obstetrics and Gynecology</td>
<td>279 (88.0 %)</td>
<td>12 (3.8 %)</td>
<td>26 (8.2 %)</td>
<td>317 (100 %)</td>
</tr>
<tr>
<td>Medicine</td>
<td>651 (92.1 %)</td>
<td>26 (3.7 %)</td>
<td>30 (4.2 %)</td>
<td>707 (100 %)</td>
</tr>
<tr>
<td>Pediatric</td>
<td>640 (83.1 %)</td>
<td>40 (5.2 %)</td>
<td>90 (11.7 %)</td>
<td>770 (100 %)</td>
</tr>
<tr>
<td>Surgery</td>
<td>1,326 (85.5 %)</td>
<td>68 (4.4 %)</td>
<td>157 (10.1 %)</td>
<td>1,551 (100 %)</td>
</tr>
</tbody>
</table>

n = number of respondents of part of study population, SD = Standard deviation, ICU = Intensive-care unit
### Summary on hand hygiene compliance of all healthcare workers (n = 364)

<table>
<thead>
<tr>
<th>% Hand hygiene compliance</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>8.9</td>
<td>0</td>
<td>19.3</td>
<td>0</td>
<td>100</td>
<td>364 (100 %)</td>
</tr>
<tr>
<td>Sex</td>
<td>* r=0.04, p=0.40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>7.6</td>
<td>0</td>
<td>17.5</td>
<td>0</td>
<td>100</td>
<td>106 (29.1 %)</td>
</tr>
<tr>
<td>Female</td>
<td>9.5</td>
<td>0</td>
<td>20.0</td>
<td>0</td>
<td>100</td>
<td>258 (70.9 %)</td>
</tr>
<tr>
<td>Working years</td>
<td>*r = -0.06, p=0.19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1 years</td>
<td>10.5</td>
<td>0</td>
<td>18.4</td>
<td>0</td>
<td>66.7</td>
<td>29 (8.0 %)</td>
</tr>
<tr>
<td>2 – 5 years</td>
<td>9.6</td>
<td>0</td>
<td>22.4</td>
<td>0</td>
<td>100</td>
<td>86 (23.6 %)</td>
</tr>
<tr>
<td>6 – 10 years</td>
<td>13.9</td>
<td>0</td>
<td>24.8</td>
<td>0</td>
<td>100</td>
<td>30 (8.2 %)</td>
</tr>
<tr>
<td>11 – 20 years</td>
<td>7.1</td>
<td>0</td>
<td>16.1</td>
<td>0</td>
<td>100</td>
<td>346 (95.0 %)</td>
</tr>
<tr>
<td>&gt; 20 years</td>
<td>44.6</td>
<td>37.6</td>
<td>35.8</td>
<td>0</td>
<td>100</td>
<td>18 (5.0 %)</td>
</tr>
<tr>
<td>Type of healthcare workers</td>
<td>*r=-0.02, p=0.74</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physicians</td>
<td>4.6</td>
<td>0</td>
<td>12.2</td>
<td>0</td>
<td>50</td>
<td>71 (19.5 %)</td>
</tr>
<tr>
<td>Nurses</td>
<td>12.8</td>
<td>1.4</td>
<td>21.0</td>
<td>0</td>
<td>100</td>
<td>118 (34.4 %)</td>
</tr>
<tr>
<td>Auxiliaries</td>
<td>8.7</td>
<td>0</td>
<td>15.9</td>
<td>0</td>
<td>100</td>
<td>58 (15.9 %)</td>
</tr>
<tr>
<td>Visitors</td>
<td>9.4</td>
<td>0</td>
<td>25.2</td>
<td>0</td>
<td>100</td>
<td>54 (14.8 %)</td>
</tr>
<tr>
<td>Nursing students</td>
<td>7.0</td>
<td>0</td>
<td>17.1</td>
<td>0</td>
<td>66.7</td>
<td>34 (9.3 %)</td>
</tr>
<tr>
<td>Medical students</td>
<td>6.0</td>
<td>0</td>
<td>20.8</td>
<td>0</td>
<td>100</td>
<td>29 (8.0 %)</td>
</tr>
<tr>
<td>Ward type</td>
<td>*r=0.16, p&lt;0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICU</td>
<td>12.2</td>
<td>0</td>
<td>22.1</td>
<td>0</td>
<td>100</td>
<td>161 (44.2 %)</td>
</tr>
<tr>
<td>Non-ICU</td>
<td>6.3</td>
<td>0</td>
<td>16.3</td>
<td>0</td>
<td>100</td>
<td>166 (45.6 %)</td>
</tr>
</tbody>
</table>

n = number of respondents of part of study population, SD = Standard deviation

*Pearson correlation (r) is provided with p values (two-tailed).
C.8: Summary on hand hygiene compliance of all healthcare workers (n = 364)

<table>
<thead>
<tr>
<th>% Hand hygiene compliance</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obstetrics and Gynecology</td>
<td>9.5</td>
<td>0</td>
<td>13.9</td>
<td>0</td>
<td>50</td>
<td>28 (7.7 %)</td>
</tr>
<tr>
<td>Medical</td>
<td>5.0</td>
<td>0</td>
<td>16.2</td>
<td>0</td>
<td>100</td>
<td>94 (25.8 %)</td>
</tr>
<tr>
<td>Peadiatric</td>
<td>9.9</td>
<td>0</td>
<td>18.1</td>
<td>0</td>
<td>100</td>
<td>53 (14.6 %)</td>
</tr>
<tr>
<td>Surgical</td>
<td>11.5</td>
<td>0</td>
<td>22.4</td>
<td>0</td>
<td>100</td>
<td>152 (41.8 %)</td>
</tr>
</tbody>
</table>

| Indication                |      |        |     |     |     |         |
| Before touching a patient | 5.2  | 0      | 12.5| 0   | 66.7| 72 (19.8 %) |
| After touching a patient  | 10.9 | 0      | 20.8| 0   | 100 | 86 (23.6 %) |
| Before clean/aseptic procedures | 8.6 | 0 | 20.6 | 0 | 100 | 47 (12.9 %) |
| After body fluid exposure/risk | 17.2 | 5.9 | 26.6 | 0 | 100 | 60 (16.5 %) |
| After touching patient surroundings | 5.2 | 0 | 13.9 | 0 | 100 | 99 (27.2 %) |

<table>
<thead>
<tr>
<th>Number of total beds</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8 beds</td>
<td>18.0</td>
<td>7.7</td>
<td>25.3</td>
<td>0</td>
<td>100</td>
<td>81 (22.3 %)</td>
</tr>
<tr>
<td>14 beds</td>
<td>5.0</td>
<td>0</td>
<td>9.1</td>
<td>0</td>
<td>28.6</td>
<td>19 (5.2 %)</td>
</tr>
<tr>
<td>30 beds</td>
<td>6.1</td>
<td>0</td>
<td>9.9</td>
<td>0</td>
<td>40</td>
<td>76 (20.9 %)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bed occupancy</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 100 %</td>
<td>5.7</td>
<td>0</td>
<td>11.4</td>
<td>0</td>
<td>50</td>
<td>105 (28.9 %)</td>
</tr>
<tr>
<td>&gt; 100 %</td>
<td>10.3</td>
<td>0</td>
<td>21.6</td>
<td>0</td>
<td>100</td>
<td>259 (71.1 %)</td>
</tr>
</tbody>
</table>

n = number of respondents of part of study population, SD = Standard deviation

*Pearson correlation (r) is provided with p values (two-tailed).
C.9: Internal consistency of domains (α) and the distribution of response on current beliefs on hand hygiene (N = 1,582)

<table>
<thead>
<tr>
<th>Theoretical domain</th>
<th>alpha (α)</th>
<th>1*</th>
<th>2*</th>
<th>3*</th>
<th>4*</th>
<th>5*</th>
<th>n (%)</th>
<th>Mean</th>
<th>Std. Err.</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>0.69</td>
<td>28</td>
<td>51</td>
<td>177</td>
<td>680</td>
<td>567</td>
<td>1,503</td>
<td>4.14</td>
<td>0.02</td>
<td>4.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.8 %</td>
<td>3.2 %</td>
<td>11.2 %</td>
<td>43.0 %</td>
<td>35.8 %</td>
<td>95.0 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skills</td>
<td>0.65</td>
<td>75</td>
<td>182</td>
<td>206</td>
<td>723</td>
<td>309</td>
<td>1,495</td>
<td>3.67</td>
<td>0.03</td>
<td>3.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.7 %</td>
<td>11.5 %</td>
<td>13.0 %</td>
<td>45.7 %</td>
<td>19.5 %</td>
<td>94.5 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social/professional role and identity</td>
<td>0.68</td>
<td>262</td>
<td>586</td>
<td>269</td>
<td>299</td>
<td>87</td>
<td>1,503</td>
<td>2.58</td>
<td>0.03</td>
<td>2.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16.7 %</td>
<td>37.0 %</td>
<td>17.0 %</td>
<td>18.9 %</td>
<td>5.5 %</td>
<td>95.0 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beliefs about capabilities</td>
<td>0.65</td>
<td>11</td>
<td>8</td>
<td>17</td>
<td>406</td>
<td>1,062</td>
<td>1,504</td>
<td>4.66</td>
<td>0.02</td>
<td>4.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7 %</td>
<td>0.5 %</td>
<td>1.1 %</td>
<td>25.7 %</td>
<td>67.1 %</td>
<td>95.1 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beliefs about consequences</td>
<td>0.64</td>
<td>76</td>
<td>3</td>
<td>66</td>
<td>412</td>
<td>1,025</td>
<td>1,582</td>
<td>4.46</td>
<td>0.02</td>
<td>4.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.8 %</td>
<td>0.2 %</td>
<td>4.2 %</td>
<td>26.0 %</td>
<td>64.8 %</td>
<td>100.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intentions</td>
<td>0.66</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>206</td>
<td>1,297</td>
<td>1,506</td>
<td>4.86</td>
<td>0.01</td>
<td>4.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0 %</td>
<td>0.0 %</td>
<td>0.2 %</td>
<td>13.0 %</td>
<td>82.0 %</td>
<td>95.2 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goals</td>
<td>0.65</td>
<td>9</td>
<td>6</td>
<td>7</td>
<td>327</td>
<td>1,154</td>
<td>1,503</td>
<td>4.74</td>
<td>0.01</td>
<td>4.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6 %</td>
<td>0.4 %</td>
<td>0.5 %</td>
<td>20.7 %</td>
<td>73.0 %</td>
<td>95.0 %</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*1 = strongly disagree to 5 = strongly agree
### C.9: Internal consistency of domains (α) and the distribution of response on current beliefs on hand hygiene (N = 1,582) (cont.)

<table>
<thead>
<tr>
<th>Theoretical domain</th>
<th>alpha (α)</th>
<th>1*</th>
<th>2*</th>
<th>3*</th>
<th>4*</th>
<th>5*</th>
<th>n (%)</th>
<th>Mean</th>
<th>Std. Err.</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory, attention and decision processes</td>
<td>0.65</td>
<td>2</td>
<td>19</td>
<td>55</td>
<td>497</td>
<td>931</td>
<td>1,504</td>
<td>4.55</td>
<td>0.02</td>
<td>4.52 4.59</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1 %</td>
<td>1.2 %</td>
<td>3.5 %</td>
<td>31.4 %</td>
<td>58.9 %</td>
<td>95.1 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental context and resources</td>
<td>0.66</td>
<td>10</td>
<td>6</td>
<td>8</td>
<td>294</td>
<td>1,183</td>
<td>1,501</td>
<td>4.75</td>
<td>0.01</td>
<td>4.73 4.78</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6 %</td>
<td>0.4 %</td>
<td>0.5 %</td>
<td>18.6 %</td>
<td>74.8 %</td>
<td>94.9 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social influences</td>
<td>0.64</td>
<td>76</td>
<td>16</td>
<td>259</td>
<td>938</td>
<td>293</td>
<td>1,582</td>
<td>3.86</td>
<td>0.02</td>
<td>3.81 3.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.8 %</td>
<td>1.0 %</td>
<td>16.4 %</td>
<td>59.3 %</td>
<td>18.5 %</td>
<td>100.0 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emotion</td>
<td>0.64</td>
<td>22</td>
<td>65</td>
<td>83</td>
<td>643</td>
<td>686</td>
<td>1,499</td>
<td>4.27</td>
<td>0.02</td>
<td>4.23 4.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.4 %</td>
<td>4.1 %</td>
<td>5.3 %</td>
<td>40.6 %</td>
<td>43.4 %</td>
<td>94.8 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Behavioural regulation</td>
<td>0.64</td>
<td>49</td>
<td>154</td>
<td>196</td>
<td>706</td>
<td>399</td>
<td>1,504</td>
<td>3.83</td>
<td>0.03</td>
<td>3.78 3.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.1 %</td>
<td>9.7 %</td>
<td>12.4 %</td>
<td>44.6 %</td>
<td>25.2 %</td>
<td>95.1 %</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*1 = strongly disagree to 5 = strongly agree
C.10: Correlations between theoretical domains about hand hygiene among participants (N = 1,582)

<table>
<thead>
<tr>
<th></th>
<th>Knowledge</th>
<th>Self-reporting</th>
<th>TDF1</th>
<th>TDF2</th>
<th>TDF3</th>
<th>TDF4</th>
<th>TDF6</th>
<th>TDF8</th>
<th>TDF9</th>
<th>TDF10</th>
<th>TDF11</th>
<th>TDF12</th>
<th>TDF13</th>
<th>TDF14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-reporting</td>
<td>0.05</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF1</td>
<td>0.01</td>
<td>-0.05</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF2</td>
<td>0.02</td>
<td>0.10***</td>
<td>-0.03</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF3</td>
<td>-0.04</td>
<td>0.03</td>
<td>-0.02</td>
<td>0.16***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF4</td>
<td>0.07*</td>
<td>0.10***</td>
<td>0.21***</td>
<td>0.11***</td>
<td>-0.01</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF6</td>
<td>0.18***</td>
<td>0.08**</td>
<td>0.06*</td>
<td>0.19***</td>
<td>0.13***</td>
<td>0.27***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF8</td>
<td>0.10***</td>
<td>0.14***</td>
<td>0.11***</td>
<td>0.16***</td>
<td>0.05</td>
<td>0.33***</td>
<td>0.27***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF9</td>
<td>0.09***</td>
<td>0.12***</td>
<td>0.15***</td>
<td>0.15***</td>
<td>0.02</td>
<td>0.41***</td>
<td>0.28***</td>
<td>0.42***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF10</td>
<td>0.12***</td>
<td>0.17***</td>
<td>0.12***</td>
<td>0.19***</td>
<td>0.08**</td>
<td>0.29***</td>
<td>0.20***</td>
<td>0.42***</td>
<td>0.33***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF11</td>
<td>0.05*</td>
<td>0.15***</td>
<td>0.15***</td>
<td>0.09***</td>
<td>-0.05</td>
<td>0.44***</td>
<td>0.31***</td>
<td>0.32***</td>
<td>0.38***</td>
<td>0.26***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF12</td>
<td>0.13***</td>
<td>0.09**</td>
<td>0.10***</td>
<td>0.23***</td>
<td>0.30***</td>
<td>0.14***</td>
<td>0.65***</td>
<td>0.17***</td>
<td>0.17***</td>
<td>0.21***</td>
<td>0.13***</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF13</td>
<td>0.02</td>
<td>0.09**</td>
<td>0.004</td>
<td>0.46***</td>
<td>0.15***</td>
<td>0.30***</td>
<td>0.19***</td>
<td>0.16***</td>
<td>0.12***</td>
<td>0.15***</td>
<td>0.15***</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF14</td>
<td>-0.04</td>
<td>0.07*</td>
<td>-0.003</td>
<td>0.27***</td>
<td>0.23***</td>
<td>0.14***</td>
<td>0.35***</td>
<td>0.18***</td>
<td>0.19***</td>
<td>0.19***</td>
<td>0.12***</td>
<td>0.19***</td>
<td>0.31***</td>
<td>1</td>
</tr>
</tbody>
</table>

*p<.05; **p<.01; ***p<.001 (two-tailed)

NOTE: TDF1 = Knowledge; TDF2 = Skills; TDF3 = Social/professional role and identity; TDF4 = Beliefs about capabilities; TDF6 = Beliefs about consequences; TDF8 = Intentions; TDF9 = Goals; TDF10 = Memory, attention and decision processes; TDF11 = Environmental context and resources; TDF12 = Social influences; TDF13 = Emotion; TDF14 = Behavioural regulation
C.11: Correlations of performed hand hygiene practice between theoretical domains among participants (n = 364)

<table>
<thead>
<tr>
<th>% compliance</th>
<th>% performed</th>
<th>% correctly performed</th>
<th>Knowledge score</th>
<th>Self-reporting</th>
<th>TDF1</th>
<th>TDF2</th>
<th>TDF3</th>
<th>TDF4</th>
<th>TDF6</th>
<th>TDF8</th>
<th>TDF9</th>
<th>TDF10</th>
<th>TDF11</th>
<th>TDF12</th>
<th>TDF13</th>
<th>TDF14</th>
</tr>
</thead>
<tbody>
<tr>
<td>% compliance</td>
<td>1</td>
<td>% performed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.91***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% correctly performed</td>
<td>0.75***</td>
<td>0.67***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge score</td>
<td>0.01</td>
<td>0.05</td>
<td>-0.10</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-reporting</td>
<td>0.04</td>
<td>0.07</td>
<td>0.03</td>
<td>0.07</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF1</td>
<td>0.05</td>
<td>0.09</td>
<td>0.07</td>
<td>0.01</td>
<td>0.05</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF2</td>
<td>-0.01</td>
<td>-0.02</td>
<td>-0.03</td>
<td>0.18*</td>
<td>-0.02</td>
<td>-0.11</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF3</td>
<td>-0.16*</td>
<td>-0.17*</td>
<td>-0.03</td>
<td>-0.08</td>
<td>-0.03</td>
<td>0.003</td>
<td>0.20**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF4</td>
<td>0.10</td>
<td>0.11</td>
<td>0.12</td>
<td>0.01</td>
<td>0.18*</td>
<td>0.22**</td>
<td>0.07</td>
<td>-0.09</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF6</td>
<td>-0.04</td>
<td>-0.02</td>
<td>-0.05</td>
<td>0.17*</td>
<td>0.09</td>
<td>0.24***</td>
<td>0.07</td>
<td>0.02</td>
<td>0.29***</td>
<td>0.25***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF8</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.05</td>
<td>0.17*</td>
<td>0.09</td>
<td>0.24***</td>
<td>0.07</td>
<td>0.02</td>
<td>0.29***</td>
<td>0.25***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF9</td>
<td>0.04</td>
<td>0.06</td>
<td>-0.0007</td>
<td>0.08</td>
<td>0.16*</td>
<td>0.17*</td>
<td>0.13</td>
<td>0.07</td>
<td>0.35***</td>
<td>0.31***</td>
<td>0.52***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF10</td>
<td>-0.07</td>
<td>-0.05</td>
<td>-0.15*</td>
<td>0.15*</td>
<td>0.14</td>
<td>0.08</td>
<td>0.04</td>
<td>0.06</td>
<td>0.31***</td>
<td>0.24***</td>
<td>0.28***</td>
<td>0.45***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF11</td>
<td>0.05</td>
<td>0.04</td>
<td>0.11</td>
<td>0.08</td>
<td>0.21*</td>
<td>0.09</td>
<td>0.04</td>
<td>-0.03</td>
<td>0.62***</td>
<td>0.31***</td>
<td>0.24***</td>
<td>0.27***</td>
<td>0.27***</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDF12</td>
<td>-0.07</td>
<td>-0.13</td>
<td>-0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>-0.01</td>
<td>-0.04</td>
<td>0.25***</td>
<td>0.48***</td>
<td>0.14</td>
<td>0.15*</td>
<td>0.11</td>
<td>0.17*</td>
<td>0.07</td>
<td>0.12</td>
<td>1</td>
</tr>
<tr>
<td>TDF13</td>
<td>0.002</td>
<td>-0.01</td>
<td>0.03</td>
<td>0.10</td>
<td>0.13</td>
<td>-0.19**</td>
<td>0.41***</td>
<td>0.16*</td>
<td>0.11</td>
<td>0.39***</td>
<td>0.17*</td>
<td>0.12</td>
<td>-0.01</td>
<td>0.18*</td>
<td>0.18**</td>
<td>1</td>
</tr>
<tr>
<td>TDF14</td>
<td>0.06</td>
<td>0.02</td>
<td>0.02</td>
<td>0.09</td>
<td>-0.04</td>
<td>-0.13</td>
<td>0.35***</td>
<td>0.35***</td>
<td>0.03</td>
<td>0.51***</td>
<td>0.10</td>
<td>0.24***</td>
<td>0.16*</td>
<td>0.16*</td>
<td>0.24***</td>
<td>0.41***</td>
</tr>
</tbody>
</table>

*p < .05; **p < .01; ***p < .001 (two-tailed)

NOTE: HH = Hand hygiene; TDF1 = Knowledge; TDF2 = Skills; TDF3 = Social/professional role and identity; TDF4 = Beliefs about capabilities; TDF6 = Beliefs about consequences; TDF8 = Intentions; TDF9 = Goals; TDF10 = Memory, attention and decision processes; TDF11 = Environmental context and resources; TDF12 = Social influences; TDF13 = Emotion; TDF14 = Behavioural regulation
Appendix D

Chapter 5 Supplementary
CERTIFICATE OF ETHICAL APPROVAL
Ethics Committee of the Faculty of Tropical Medicine, Mahidol University
420/6 Ratchawithi Rd., Ratchathewi, Bangkok 10400, Thailand

This Certificate of Ethical Approval (MUTM 2012-042-01) applies to the

Project entitled: A stepped wedge cluster randomised controlled trial to evaluate the impact of
a multimodal hand hygiene intervention at Sappasitiprasong Hospital, Ubon
Ratchathani

EC Submission No.: TMEC 12-009

with the following relevant documents:

1) Research Proposal (FTM ECF-019-02); English version 1.2 date 20 August 2012
2) Participant Information Sheet (FTM ECF-020-00); Thai version 1.1 date 20 August 2012
3) Informed Consent Form (FTM ECF-021-02); Thai version 1.1 date 20 August 2012
4) Questionnaires Form; Thai version 1.1 date 23 July 2012
5) Observation Form; Thai version 1.1 date 23 July 2012
6) Case Record Form; English version 1.0 date 9 January 2012

Principal Investigator: Dr. Direk Limmathurosakul

Affiliation: Department of Tropical Hygiene,
Faculty of Tropical Medicine, Mahidol University

This project has been approved for the period
from 29 August 2012 to 28 August 2013

The Ethics Committee of Faculty of Tropical Medicine certify that we are in compliance with
Declaration of Helsinki, ICH Guidelines for Good Clinical Practice and other International Guidelines for
Human Research Protection.

Signature .......................................................... (Prof. Srisin Khusmith)

Chairperson (Panel 2) Ethics Committee of the Faculty of Tropical Medicine
Date 31 AUG 2012

Signature .......................................................... (Mrs. Pornpimon Adams)

Member and Secretary Ethics Committee of the Faculty of Tropical Medicine
Date 31 AUG 2012
คู่มือโครงการวิจัย

เรื่อง: ศึกษาเปรียบเทียบแบบสุ่มเป็นขั้นเพื่อประเมินผลการส่งเสริมการล้างมือในโรงพยาบาลสรรพสิทธิ์
ประสงค์: อุบลราชธานี “A Stepped Wedge Cluster Randomised Controlled Trial to Evaluate the Impact of a Multimodal Hand Hygiene Intervention at Sappasitthiprasong Hospital, Ubon Ratchatani”

วัตถุประสงค์หลัก
เพื่อประเมินพฤติกรรมการล้างมือของเจ้าหน้าที่ทางการแพทย์ที่ได้รับการส่งเสริมการล้างมือตามแนวทางขององค์การอนามัยโลก (WHO) ด้วยการสังเกตการปฏิบัติตามคำแนะนำของ 5 ข้อบ่งชี้ในการทาความสะอาดมือเพื่อการพยาบาล

ระยะเวลาดำเนินโครงการ
ตั้งแต่วันที่ 1 เมษายน พ.ศ. 2556 ถึงวันที่ 31 ตุลาคม พ.ศ. 2557

เจ้าหน้าที่วิจัย
1. นายแพทย์ปราโมทย์ ศรีสาอางค์ ประธานคณะกรรมการป้องกันและควบคุมการติดเชื้อในโรงพยาบาล
2. นางศิริรัตน์ เชาวรัตน์ หัวหน้ากลุ่มงานป้องกันและควบคุมการติดเชื้อในโรงพยาบาล
3. นางสมบูรณ์ นันตโลหิต เจ้าหน้าที่กลุ่มงานป้องกันและควบคุมการติดเชื้อในโรงพยาบาล
4. นางสมศิริ บุญส่อง เจ้าหน้าที่กลุ่มงานป้องกันและควบคุมการติดเชื้อในโรงพยาบาล
5. นางสาวทวีดีมา อ่อนนุช เจ้าหน้าที่กลุ่มงานป้องกันและควบคุมการติดเชื้อในโรงพยาบาล
6. นายแพทย์เตา เจมส์ดุษฎีกุล ผู้วิจัยหลัก
7. นางสาวขวัญใจ คงห่วนสวัสดิ์ พยาบาลวิชาชีพ
8. นางสาวปิยวรรณ วิลาบุตร ผู้ช่วยเจ้าหน้าที่วิจัย
9. นางสาวถิ่นสกุล แหวนวงษ์ ผู้ช่วยเจ้าหน้าที่วิจัย
รายละเอียดการศึกษา

โรคหลายโรคติดต่อโดยมีมือเป็นตัวนำเชื้อโรคเข้าสู่ร่างกาย รวมไปถึงการติดเชื้อที่เกิดขึ้นจากการรับการรักษาในโรงพยาบาลเป็นสาเหตุสั้นอายุของการเจ็บป่วยและการตายทั่วโลก และโดยเฉพาะอย่างยิ่งในโรงพยาบาลที่มีทรัพยากรจำกัดอย่างมาก การวิเคราะห์ผลของเจ้าหน้าที่ทางการแพทย์ซึ่งรวมถึงการล้างมือที่ดีขึ้น โดยเฉพาะอย่างยิ่งที่เกี่ยวกับการใช้จ่ายเพิ่มขึ้นของแอลกอฮอล์เพื่อการล้างมือ (ในกรณีที่มีประสิทธิภาพมากที่สุดของการลดการติดเชื้อค้างล้างการกระทำ (Hand Hygiene) เป็นมาตรการสําคัญที่ช่วยป้องกันและลดอุบัติการณ์ของการติดเชื้อในโรงพยาบาลและเป็นมาตรการที่มีประสิทธิภาพรวดเร็ว ประหยัดค่าใช้จ่ายที่สุด ดังนั้นจึงจําเป็นที่เจ้าหน้าที่ทางการแพทย์ต้องล้างมืออย่างถูกวิธี

ในการนี้ คณะผู้วิจัยโรงพยาบาลสรรพสิทธิประสงค์จังหวัดอุบลราชธานี โดย นายแพทย์ปราโมทย์ศรีสราส และงานป้องกันและควบคุมการติดเชื้อในโรงพยาบาล ร่วมกับนายแพทย์ติรุด อัมรฉาส อาจารย์ประจาหน่วยวิจัยโรคติดต่อมาตุ๊กล-อีโคซัส คณะเวชศาสตร์เขตร้อน มหาวิทยาลัยมหิดล เลือกเห็นความสำคัญของการส่งเสริมการล้างมือ (Hand Hygiene) ในหมู่เจ้าหน้าที่ของโรงพยาบาล จึงได้มีการทดลองร่วมมือที่จะทำโครงการวิจัยเรื่อง "การศึกษาเปรียบเทียบแบบสุ่มเปรียบเป็นขั้นตอนเพื่อประเมินผลการส่งเสริมการล้างมือในโรงพยาบาลสรรพสิทธิประสงค์ จ. อุบลราชธานี" คณะผู้วิจัยจึงได้จัดตั้งทีมวิจัยขึ้นมาเพื่อเป็นแนวทางในการส่งเสริมการล้างมือในหมู่เจ้าหน้าที่ทางการแพทย์ให้สอดคล้องกับแนวทางในการส่งเสริมขององค์การอนามัยโลก(WHO Guideline on Hand Hygiene in Health Care)

การศึกษานี้เป็นการศึกษาเปรียบเทียบแบบสุ่มเปรียบเป็นขั้นตอนแบบไปข้างหน้า ซึ่งจะทำสําหรับการศึกษาในเจ้าหน้าที่ทางการแพทย์ในหอผู้ป่วยในทุกหอผู้ป่วยของโรงพยาบาลสรรพสิทธิประสงค์) ขนาด 1,000เตียง (ที่จัดตั้งอุบลราชธานี รูปแบบการศึกษาแบบ stepped wedge เป็นการศึกษาประเภทหนึ่งของการสุ่มตัวอย่างเปรียบเทียบ ซึ่งการศึกษาประเภทนี้จะทำให้การศึกษาได้มีความชัดเจนชัดเจนด้านการต่างกันของผลลัพธ์ที่เห็นได้จากการต่างกันของผลลัพธ์ที่อยู่ในหองนั้นจะเป็นประโยชน์และมีคิวจัดการด้านการแพทย์ การกระจายการเปลี่ยนแปลงต่าง ๆ นั้นจะถูกส่งผ่านโดยเจ้าหน้าที่อัจฉริยะและพยาบาลผู้รับผิดชอบการติดเชื้อในแผนภูมิป่วยในที่จะได้รับการศึกษานี้เพิ่มเติม
ผู้วิจัยคาดหวังว่า ผลการศึกษาจะสามารถนำไปใช้ได้กับโรงพยาบาลอื่นๆ ที่มีความจำกัดทางด้านทรัพยากร ในประเทศไทยและประเทศกำลังพัฒนาอื่นๆ นอกจากนี้ผลการวิจัยจะให้ข้อมูลที่สำคัญในการประเมินทางเศรษฐศาสตร์ของการกระตุ้นการล้างมือและผลในการควบคุมการติดเชื้อ เพื่อพิจารณาอย่างครอบคลุมว่าการกระตุ้นดังกล่าวจะมีแนวโน้มที่จะมีประสิทธิภาพอย่างไร
การส่งเสริมการล้างมือตามแนวทางขององค์การอนามัยโลก

โรคติดเชื้อในโรงพยาบาลเป็นโรคติดเชื้อที่รุนแรงและมีผลกระทบทางเศรษฐกิจอย่างมีนัยสำคัญทางสถิติกับผู้ป่วยและระบบสุขภาพในโลก ดังนั้นการทำความสะอาดมือที่ดี เป็นงานที่ง่ายและเป็นวิธีที่เหมาะสมที่จะสามารถช่วยให้ผู้ป่วยได้

องค์การอนามัยโลกได้พัฒนาหลักฐานเกี่ยวกับการดำเนินการทำความสะอาดมือในสถานบริการเพื่อสนับสนุนสถานบริการสุขภาพเพื่อให้มั่นใจในการดำเนินการทำความสะอาดมือและการลดลงของโรคติดเชื้อในโรงพยาบาล

ผู้มีการดำเนินการนี้ได้รับการพัฒนาขึ้นเพื่อช่วยสถานบริการสุขภาพในการดำเนินการพัฒนาการทำความสะอาดมือตามคู่มือเกี่ยวกับคู่มือการดำเนินการขององค์การอนามัยโลก

กลยุทธ์ที่ได้รับการพัฒนาขึ้นในผู้มีการดำเนินการนี้ได้รับการออกแบบเพื่อใช้กับสถานบริการสุขภาพอื่น ๆ โดยไม่คำนึงถึงระดับของทรัพยากรหรือสถานบริการ ได้เริ่มต้นดำเนินการก่อนนายทหารความสะอาดมือไปแล้ว หรือไม่ วิธีการที่ผู้มีการดำเนินการต้องการในการดำเนินการทำความสะอาดมือโดยบุคคลที่มีสุขภาพที่ดีมีงานเกี่ยวกับผู้ป่วย ผ่านการดำเนินงานที่นำเสนอโดยกลยุทธ์ การพัฒนาโครงสร้างการดำเนินการก่อนนายทหารความicipation ความรู้และการรับรู้เกี่ยวกับการดำเนินการทำความสะอาดมือและโรคติดเชื้อในโรงพยาบาล และสภาพแวดล้อมที่ปลอดภัยสำหรับผู้ป่วยจะหมายถึงการดำเนินงานที่ประสบผลสำเร็จ เป้าหมายที่สำคัญคือการลดจำนวนการแพร่กระจายของโรคติดเชื้อและโรคติดเชื้อในโรงพยาบาลและผู้ป่วยที่สามารถป้องกันโรคติดเชื้อในโรงพยาบาลและป้องกันการสูญเสียทรัพยากรและรักษาชีวิต
กลยุทธ์ในการพัฒนาการทำความสะอาดมือขององค์กรอนามัย

1. การเปลี่ยนแปลงระบบ (System change): ทำให้มั่นใจได้ว่าโครงสร้างพื้นฐานที่จำเป็นอยู่ในที่ที่บุคลากรสามารถเข้าถึงได้ เพื่อปฏิบัติในการทำความสะอาดมือ ซึ่งประกอบด้วยสององค์ประกอบดังนี้
   - สามารถเข้าถึงความปลอดภัย ระบบจำเป็นที่ค่อนข้างรวมถึงสบู่และผ้าเช็ดมือ
   - เข้าถึงแอลกอฮอล์มือ ณ จุดต่างๆให้ได้อย่างง่ายดาย
2. การอบรมให้ความรู้ (Training and education): จัดให้มีการสอนเป็นประจำเกี่ยวกับความสำคัญในการทำความสะอาดมือ บนพื้นฐานของ “5 ข้อบ่งชี้ในการทำความสะอาดมือเพื่อการพยาบาลและกระบวนการที่” ถูกต้องสําหรับการอุปกรณ์และการถูมือให้แก่บุคลากรสุขภาพทุกคน

5 ข้อบ่งชี้ในการทำความสะอาดมือเพื่อการพยาบาล
3. การประเมินและให้ข้อมูลย้อนกลับ (Evaluation and feedback): ตรวจสอบการปฏิบัติและโครงสร้างพื้นฐานในการทำความสะอาดมือ พร้อมด้วยการรับรู้และความรู้ที่เกี่ยวข้องในบุคลากรสุขภาพ ขณะที่ให้ข้อมูลเกี่ยวกับประสิทธิภาพในการปฏิบัติและให้ข้อมูลย้อนกลับไปยังบุคลากร
4. สิ่งเตือนใจในสถานบริการ (Reminder at workplace): กระตุ้นเตือนบุคลากรสุขภาพเกี่ยวกับความสำคัญเกี่ยวกับการทำความสะอาดมือและเกี่ยวกับตัวชี้วัดที่เหมาะสมรวมถึงกระบวนการในการด้เนินการ
5. การสร้างสภาพแวดล้อมที่ส่งเสริมการล้างมือในหอผู้ป่วย (Ward safety climate): สร้างสภาพแวดล้อมและการรับรู้ซึ่งส่งเสริมให้มีความตระหนักที่เพิ่มขึ้นเกี่ยวกับประเด็นความปลอดภัยของผู้ป่วย ในขณะที่มีการรับประกันว่าการพิจารณาถึงข้อกับการพัฒนาการทำความสะอาดมือเป็นสิ่งสำคัญที่สุดในทุกระดับชีวิตประกอบด้วย
   - การเข้ามีส่วนร่วมในกิจกรรมทางการระดับแผนก ระดับหอผู้ป่วยและระดับบุคคล
   - การตระหนักถึงความสามารถส่วนบุคคลและสถาบันในการเปลี่ยนแปลงและพัฒนาประสิทธิภาพ
   - การมีส่วนร่วมกับผู้ป่วยและองค์กรผู้ป่วย
ขั้นตอนดำเนินการ

ประกอบด้วย 5 ขั้นตอนในการดำเนินการตามลำดับ ดังนี้

ขั้นตอนที่ 1: การประเมินพื้นฐาน สร้างองค์ความรู้เกี่ยวกับสถานการณ์ปัจจุบัน – ของหอผู้ป่วยของท่าน
  • ดำเนินการประเมินพื้นฐานเกี่ยวกับการปฏิบัติ การรับรู้ ความรู้และโครงสร้างที่สามารถใช้ได้ในการทำความสะอาดมือ

**ซึ่งในการศึกษานี้ท่านจะต้องเลือกกลยุทธ์การส่งเสริมการล้างมือที่คิดว่าเหมาะสมกับหอผู้ป่วยของท่านหลังจากนั้นนำไปสู่แนวทางการปฏิบัติ ซึ่งในแต่ละกลยุทธ์จะมีแนวทางการประเมินที่แตกต่างกัน ดังต่อไปนี้**

1) การเปลี่ยนแปลงระบบ(System change)
  ประเมินองค์ประกอบที่จำเป็นต่อการล้างมือทุกเดือน

2) การอบรมให้ความรู้(Training and education)
  ประเมินความรู้พื้นฐานของการล้างมือและการติดเชื้อในโรงพยาบาลของเจ้าหน้าที่ในหอผู้ป่วยทุกคนในหอผู้ป่วย ทุก 3 เดือน เพื่อหาจุดกลุ่มการอบรมให้เหมาะสมกับคนโดยคณะวิจัยจะเป็นผู้เตรียมแบบสอบถามพร้อมทั้งเอกสารประกอบการสอนให้แก่เจ้าหน้าที่

3) การประเมินและให้ข้อมูลย้อนกลับ(Evaluation and feedback)
  ประเมินสถานการณ์การล้างมือและอัตราการติดเชื้อในโรงพยาบาลของท่านค้นหาผู้ปฏิบัติการล้างมืออย่างถูกต้อง และแต่งตั้งให้เป็น “Hand hygiene star” เพื่อเป็นผู้ช่วยในการให้ข้อมูลย้อนกลับกับเจ้าหน้าที่ในหอผู้ป่วยที่ล้างมือไม่ถูกต้อง โดยจะต้องมีการคัดเลือก

4) สิ่งเตือนใจในสถานบริการ(Reminder at workplace)
  ประเมินว่าต้องการสิ่งเตือนใจประเภทใดบ้างและจำนวนเท่าไหร่ โดยคณะวิจัยจะเป็นผู้เตรียมแบบสิ่งเตือนใจให้แก่หอผู้ป่วย

5) การสร้างสภาพแวดล้อมที่ส่งเสริมการล้างมือในหอผู้ป่วย(Ward safety climate)
แนวทางที่ออผู้ป่วยริเริ่มขึ้นเอง

ขั้นตอนที่ 2: การเตรียมสถานบริการสำหรับด้านการ

- สร้างความมั่นใจว่ามีการเตรียมความพร้อมของสถานบัน รวมถึงการได้มาซึ่งทรัพยากรที่จำเป็นทั้ง
 ทรัพยากรบุคคลและการเงิน, ระบุผู้นำที่สำคัญเพื่อเป็นหลักในการโปรแกรมรวมถึงผู้ประสานงานและรองผู้ประสานงาน  โดยแผนที่เหมาะสมจะต้องประกอบด้วยแผนที่ทางดินไปที่สถานที่ที่ จำเป็นสำหรับโปรแกรมทั้งหมด

ขั้นตอนที่ 3: ดำเนินการพัฒนากิจกรรม

- ดำเนินการประเมินพื้นฐานเกี่ยวกับการปฏิบัติ, การรับรู้, ความรู้และโครงสร้างที่สามารถใช้ได้ในการ ทำความสะอาดมือ

ขั้นตอนที่ 4: ติดตามประเมินผล ประเมินผลการทำงานจากการดำเนินงาน – ดำเนินการประเมินพื้นฐานเกี่ยวกับการปฏิบัติความรู้และโครงสร้างที่สามารถใช้ได้ในการทำความ, การรับรู้, สะอาดมือ

ขั้นตอนที่ 5: วางแผนอย่างต่อเนื่องและทบทวน

- พัฒนาแผนปฏิบัติและทบทวนวางแผนอย่างต่อเนื่อง เพื่อให้มีนั้นใจถึงความยั่งยืนในระยะยาว

วัตถุประสงค์ทั้งหมดนี้เพื่อปลูกฝังการทำความสะอาดมือให้เป็นส่วนหนึ่งที่สำคัญของวัฒนธรรมใน สถานบริการสุขภาพ
การพัฒนาการทำความสะอาดมือตามแนวทางขององค์การอนามัยโลก

5 กลยุทธ์ขององค์การอนามัยโลก

ขั้นตอนดำเนินการ
1. การประเมินพื้นฐาน
2. การเตรียมสถานบริการ
3. การดำเนินการ
4. การติดตามประเมินผล
5. บทบาทและวางแผน
ทางคณะผู้วิจัยได้มีการประยุกต์แนวแนวทางการส่งเสริมการล้างมือตาม 5 กลยุทธ์ขององค์การอนามัยโลก และเปิดโอกาสให้ทางหอผู้ป่วยพัฒนากลยุทธ์ของตนเองได้หากในแต่ละหอผู้ป่วยมีเห็นว่าต้องการส่งเสริมการล้างมือในแนวทางที่แตกต่างจาก แนวทางขององค์การอนามัยโลก ซึ่งกลยุทธ์ของการศึกษานี้จะมีทั้งหมด 6 แนวทาง ดังนี้

- การเปลี่ยนแปลงระบบ (System change)
- การอบรม/ให้ความรู้ (Training and education)
- การประเมินและให้ข้อมูลย้อนกลับ (Evaluation and feedback)
- สิ่งเตือนใจในสถานบริการ (Reminder at workplace)
- การสร้างสภาพแวดล้อมที่ส่งเสริมการล้างมือในห้องผู้ป่วย (Ward safety climate)
- แนวทางที่ห้องผู้ป่วยสร้างขึ้นเอง (Creative idea)
เอกสารชี้แจงโครงการวิจัย

เรื่อง: ศึกษาเปรียบเทียบแบบสุ่มเป็นขั้นเพื่อประเมินผลการส่งเสริมการล้างมือในโรงพยาบาลสรรพสิทธิประสงค์

จ.อุบลราชธานี “A Stepped Wedge Cluster Randomised Controlled Trial to Evaluate the Impact of a Multimodal Hand Hygiene Intervention at Sappasitthiprasong Hospital, Ubon Ratchatani”

วัตถุประสงค์หลัก

เพื่อประเมินพฤติกรรมการล้างมือของเจ้าหน้าที่ทางการแพทย์ที่ได้รับการส่งเสริมการล้างมือตามแนวทางขององค์การอนามัยโลก (WHO) ด้วยการสังเกตการปฏิบัติตามคู่มือการล้างมือเป็นเวลา 5 ชั่วโมงในการทำงาน

ระยะเวลาดำเนินโครงการ

ตั้งแต่วันที่ 1 เมษายน พ.ศ. 2556 ถึงวันที่ 31 ตุลาคม พ.ศ. 2557

เจ้าหน้าที่วิจัย

<table>
<thead>
<tr>
<th>ลำดับ</th>
<th>ชื่อ</th>
<th>หน้าที่</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>นายแพทย์ปราโมทย์ ศรีส าอางค์</td>
<td>ประธานคณะกรรมการป้องกันและควบคุมการติดเชื้อในโรงพยาบาล</td>
</tr>
<tr>
<td>2.</td>
<td>นางสาววัชรินทร์ ขาวรัตน์</td>
<td>หัวหน้ากลุ่มงานป้องกันและควบคุมการติดเชื้อในโรงพยาบาล</td>
</tr>
<tr>
<td>3.</td>
<td>นางสมบูรณ์ นันตโลหิต</td>
<td>เจ้าหน้าที่กลุ่มงานป้องกันและควบคุมการติดเชื้อในโรงพยาบาล</td>
</tr>
<tr>
<td>4.</td>
<td>นางสมรักษ์ บุญส่ง</td>
<td>เจ้าหน้าที่กลุ่มงานป้องกันและควบคุมการติดเชื้อในโรงพยาบาล</td>
</tr>
<tr>
<td>5.</td>
<td>นางสาวธิดีมา อ่อนสุด</td>
<td>เจ้าหน้าที่กลุ่มงานป้องกันและควบคุมการติดเชื้อในโรงพยาบาล</td>
</tr>
<tr>
<td>6.</td>
<td>นายแพทย์นิรันดร ทวีสุสุก</td>
<td>ผู้วิจัยหลัก</td>
</tr>
<tr>
<td>7.</td>
<td>นางสาวณัฐพร ชูรุ่งเรือง</td>
<td>ทายาทวิชาชีพ</td>
</tr>
<tr>
<td>8.</td>
<td>นางสาวปิยวรรณ วิลาบุตร</td>
<td>ผู้ช่วยเจ้าหน้าที่วิจัย</td>
</tr>
<tr>
<td>9.</td>
<td>นางสาวเจิมสิริ สัมพันธ์</td>
<td>ผู้ช่วยเจ้าหน้าที่วิจัย</td>
</tr>
</tbody>
</table>
รายละเอียดของกลยุทธ์ในการส่งเสริมการทำความสะอาดมือ

กลยุทธ์ในการพัฒนาการทำความสะอาดมือขององค์การอนามัยโลกที่นำมาประยุกต์ใช้ให้สอดคล้องกับแต่ละหอผู้ป่วยได้แก่

1. การเปลี่ยนแปลงระบบ (System change): ทำให้มั่นใจได้ว่าโครงสร้างพื้นฐานที่จำเป็นอยู่ในที่บุคลากรสามารถเข้าถึงได้ เพื่อปฏิบัติในการทำความสะอาดมือ ซึ่งประกอบด้วย 2 องค์ประกอบที่จำเป็น ดังนี้
   - สามารถเข้าถึงความปลอดภัย ระบบจ่ายน้ำที่ต่อเนื่องรวมถึงสบู่และผ้าเช็ดมือ
   - เข้าถึงแอลกอฮอล์ถูมือได้ที่จุดดูแลผู้ป่วยที่มี

2. การอบรมให้ความรู้ (Training and education): จัดให้มีการสอนเป็นประจำเกี่ยวกับความสำคัญในการทำความสะอาดมือ บนพื้นฐานของ “5 ข้อบ่งชี้ในการทำความสะอาดมือเพื่อการพยาบาล” และกระบวนการที่ถูกต้องสำหรับการถูมือและการล้างมือให้แก่บุคลากรสุขภาพทุกคน

3. การประเมินและให้ข้อมูลย้อนกลับ (Evaluation and feedback): ตรวจสอบการปฏิบัติและโครงสร้างพื้นฐานในการทำความสะอาดมือ เรื่อยด้วยการรับรู้และความรู้ที่เกี่ยวข้องในบุคลากรสุขภาพ ขณะที่ให้ข้อมูลเกี่ยวกับประสิทธิภาพในการปฏิบัติ และให้ข้อมูลย้อนกลับไปยังบุคลากร
4. สิ่งเตือนใจในสถานบริการ (Reminder at workplace): กระตุ้นเตือนบุคลากรสุขภาพเกี่ยวกับความสำคัญในการทำความสะอาดมือและตัวชี้วัดที่เหมาะสม รวมถึงกระบวนการในการดำเนินการ

5. การสร้างสภาพแวดล้อมที่ส่งเสริมการล้างมือในหอผู้ป่วย (Ward safety climate): สร้างสภาพแวดล้อมและกระตุ้นบุคลากรเกี่ยวกับความสำคัญในการล้างมือ การตีความและส่งเสริมการพัฒนาการทำความสะอาดมือเป็นลำดับความสำคัญขั้นสูงในทุกระดับของสถานบริการ ซึ่งประกอบด้วย

- การเข้ามีส่วนร่วมในกิจกรรมทั้งในระดับแผนก ระดับหอพยาบาล และระดับบุคคล
- การระดับนักฮีเลี่ยนประจำบ้านและสถาบันในการเปลี่ยนแปลงและพัฒนาประสิทธิภาพส่วนบุคคล
- การมีส่วนร่วมกันผู้ป่วยและองค์กรผู้ป่วย

ทางคณะผู้วิจัยได้มีการประหยัดค์แนวทางการทำงานที่ส่งเสริมการล้างมือตาม 5 กลยุทธ์ขององค์การอนามัยโลกและเปิดโอกาสให้หอพยาบาลและกลุ่มที่เกี่ยวข้องทั้งในระดับแผนก ระดับหอพยาบาล และระดับบุคคล ดำเนินการตามแนวทางที่แตกต่างจากแนวทางขององค์การอนามัยโลก ซึ่งกลุ่มที่มีการมีส่วนร่วมกันผู้ป่วยและองค์กรผู้ป่วย

ทางคณะผู้วิจัยได้ทั้งหมด 6 แนวทาง ดังนี้

1. การเปลี่ยนแปลงระบบ (System change)
2. การอบรมให้ความรู้ (Training and education)
3. การประเมินและให้ข้อมูลย้อนกลับ (Evaluation and feedback)
4. สิ่งเตือนใจในสถานบริการ (Reminder at workplace)
5. การสร้างสภาพแวดล้อมที่ส่งเสริมการล้างมือในหอผู้ป่วย (Ward safety climate)
6. แนวทางที่หอพยาบาลเริ่มขึ้นเอง

รายละเอียดเพิ่มเติมในแต่ละกลุ่มที่จะจัดแบ่งแต่ละหอพยาบาลในโครงการผู้วิจัย วันและเวลาที่จะดำเนินการให้สังเกตุในในการส่งเสริมการล้างมือในแต่ละหอพยาบาลที่ได้กำหนดไว้ในโครงการวิจัย
โดยคณะผู้วิจัยจะขออนุญาตดำเนินการดังนี้
1. ขออนุญาตเข้าพบหัวหน้าหอผู้ป่วยและพยาบาลควบคุมการติดเชื้อประจำหอผู้ป่วย ตามวันและเวลาที่กำหนดไว้ในโครงการวิจัย ซึ่งจะใช้เวลา 2 วัน 1 ชั่วโมงในแต่ละหอผู้ป่วย ในการดำเนินการเพื่อพัฒนาแนวทางการส่งเสริมการล้างมือให้สอดคล้องกับแนวทางขององค์การอนามัยโลก (WHO Guideline on Hand Hygiene in Health Care) และให้แต่ละหอผู้ป่วยดำเนินการตามแนวทางที่ได้ตกลงกันจนสิ้นสุดโครงการ
2. ขออนุญาตสัมภาษณ์หัวหน้าหอผู้ป่วยและพยาบาลควบคุมการติดเชื้อประจำหอผู้ป่วย ในประเด็นที่เกี่ยวข้องกับ "อุปกรณ์และค่าใช้จ่ายในการส่งเสริมการล้างมือ" ตามระยะเวลาที่กำหนดไว้ในโครงการวิจัย
3. ขอความร่วมมือเจ้าหน้าที่ประจำหอผู้ป่วยในทุกท่าน ตอบแบบสอบถามเกี่ยวกับ "ความรู้และทัศนคติที่มีต่อการล้างมือ" ทุกๆ 3 เดือนตลอดระยะเวลาดำเนินโครงการวิจัย
4. ขอความร่วมมือแต่ละหอผู้ป่วยตอบแบบสอบถามเพื่อใช้เป็นข้อมูลในการพัฒนาแนวทางการส่งเสริมการล้างมือให้สอดคล้องกับแนวทางขององค์การอนามัยโลก (WHO Guideline on Hand Hygiene in Health Care)

หลังจากที่ท่านได้ทบทวนกลยุทธ์ในการพัฒนาระบบความสะอาดข้างต้นแล้ว ท่านคิดว่ากลยุทธ์ใดที่เหมาะสมที่จะใช้เป็นแนวทางในการส่งเสริมการล้างมือในหอผู้ป่วยของท่าน

1. การเปลี่ยนแปลงระบบ (System change)

เหมาะสม เพราะ........................................................
........................................................
........................................................
........................................................
........................................................
........................................................
........................................................

ไม่เหมาะสม เพราะ........................................................
........................................................
........................................................
........................................................
........................................................
........................................................
........................................................
2. การอบรมให้ความรู้ (Training and education)
เหมาะสม เพราะ …………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
เหมาะสม เพราะ …………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
ไม่เหมาะสม เพราะ …………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
3. การประเมินและให้ข้อมูลย้อนกลับ (Evaluation and feedback)
เหมาะสม เพราะ …………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
ไม่เหมาะสม เพราะ …………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
……………………………………………………………………………………………………………………
4. สิ่งเตือนใจในสถานบริการ (Reminder at workplace)
เหมาะสม เพราะ……………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
ไม่เหมาะสม เพราะ……………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………

5. การสร้างสภาพแวดล้อมที่ส่งเสริมการล้างมือในห้องผู้ป่วย (Ward safety climate)
เหมาะสม เพราะ……………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
ไม่เหมาะสม เพราะ……………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………
6. แนวทางที่ก่อคุณประโยชน์เอง หากท่านคิดเห็นว่าต้องการส่งเสริมการล้างมือในแนวทางที่แตกต่างจากแนวทางขององค์การอนามัยโลก โปรดแสดงความคิดเห็น
### D.3: Description of assessment of inter-rater reliability

<table>
<thead>
<tr>
<th>No.</th>
<th>Total opportunities</th>
<th>Date</th>
<th>Number of observers</th>
<th>Kappa</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
<td>Hand hygiene practice</td>
<td>Step</td>
</tr>
<tr>
<td>1</td>
<td>118</td>
<td>13-Nov-13</td>
<td>2</td>
<td>0.923</td>
<td>0.538</td>
<td>0.599</td>
<td>0.600</td>
</tr>
<tr>
<td>2</td>
<td>105</td>
<td>14-Nov-13</td>
<td>2</td>
<td>0.975</td>
<td>1.000</td>
<td>0.946</td>
<td>0.884</td>
</tr>
<tr>
<td>3</td>
<td>105</td>
<td>3-Jan-14</td>
<td>2</td>
<td>0.987</td>
<td>0.793</td>
<td>0.791</td>
<td>0.795</td>
</tr>
<tr>
<td>4</td>
<td>118</td>
<td>31-Jan-14</td>
<td>2</td>
<td>1.000</td>
<td>0.968</td>
<td>0.935</td>
<td>0.919</td>
</tr>
<tr>
<td>5</td>
<td>118</td>
<td>24-Feb-14</td>
<td>2</td>
<td>0.950</td>
<td>0.930</td>
<td>0.859</td>
<td>1.000</td>
</tr>
<tr>
<td>6</td>
<td>118</td>
<td>21-Apr-14</td>
<td>3</td>
<td>0.840</td>
<td>0.950</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>7</td>
<td>118</td>
<td>30-May-14</td>
<td>3</td>
<td>0.974</td>
<td>0.932</td>
<td>0.832</td>
<td>1.000</td>
</tr>
<tr>
<td>8</td>
<td>120</td>
<td>30-Jun-14</td>
<td>3</td>
<td>1.000</td>
<td>0.936</td>
<td>0.935</td>
<td>1.000</td>
</tr>
<tr>
<td>9</td>
<td>120</td>
<td>1-Aug-14</td>
<td>3</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>10</td>
<td>120</td>
<td>29-Aug-14</td>
<td>3</td>
<td>0.984</td>
<td>0.968</td>
<td>0.967</td>
<td>0.967</td>
</tr>
<tr>
<td>11</td>
<td>125</td>
<td>26-Sep-14</td>
<td>3</td>
<td>1.000</td>
<td>0.779</td>
<td>0.777</td>
<td>1.000</td>
</tr>
<tr>
<td>12</td>
<td>110</td>
<td>30-Oct-14</td>
<td>2</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>13</td>
<td>108</td>
<td>27-Nov-14</td>
<td>2</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>14</td>
<td>116</td>
<td>22-Dec-14</td>
<td>2</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>
D.3: Description of assessment of inter-rater reliability (cont.)

<table>
<thead>
<tr>
<th>No.</th>
<th>Total opportunities</th>
<th>Date</th>
<th>Number of observers</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>15</td>
<td>107</td>
<td>30-Jan-15</td>
<td>2</td>
<td>1.000</td>
</tr>
<tr>
<td>16</td>
<td>113</td>
<td>27-Feb-15</td>
<td>2</td>
<td>1.000</td>
</tr>
<tr>
<td>17</td>
<td>103</td>
<td>30-Mar-15</td>
<td>2</td>
<td>1.000</td>
</tr>
<tr>
<td>18</td>
<td>106</td>
<td>29-Apr-15</td>
<td>2</td>
<td>1.000</td>
</tr>
</tbody>
</table>
D.4: Descriptive statistics for characteristics and covariates in the study by hand hygiene events vs. all observed events [n]

<table>
<thead>
<tr>
<th>Variables</th>
<th>Before intervention</th>
<th>After intervention</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>8,013 vs. 12,598</td>
<td>4,943 vs. 8,111</td>
<td>12,956 vs. 20,709</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1,917 vs. 3,455</td>
<td>886 vs. 1,766</td>
<td>2,803 vs. 5,221</td>
</tr>
<tr>
<td>Female</td>
<td>6,096 vs. 9,143</td>
<td>4,057 vs. 6,345</td>
<td>10,153 vs. 15,488</td>
</tr>
<tr>
<td>Type of HCWs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctor</td>
<td>497 vs. 500</td>
<td>140 vs. 140</td>
<td>637 vs. 640</td>
</tr>
<tr>
<td>Registered Nurse</td>
<td>4,244 vs. 5,705</td>
<td>2,702 vs. 3,746</td>
<td>6,946 vs. 9,451</td>
</tr>
<tr>
<td>Technical Nurse</td>
<td>147 vs. 202</td>
<td>139 vs. 231</td>
<td>286 vs. 433</td>
</tr>
<tr>
<td>Nursing Assistant</td>
<td>335 vs. 619</td>
<td>230 vs. 402</td>
<td>565 vs. 1,021</td>
</tr>
<tr>
<td>Nursing Aide</td>
<td>1,387 vs. 3,229</td>
<td>904 vs. 1,964</td>
<td>2,291 vs. 5,193</td>
</tr>
<tr>
<td>Worker</td>
<td>523 vs. 1,460</td>
<td>461 vs. 1,261</td>
<td>984 vs. 2,721</td>
</tr>
<tr>
<td>Medical Student</td>
<td>118 vs. 118</td>
<td>29 vs. 29</td>
<td>147 vs. 147</td>
</tr>
<tr>
<td>Nursing Student</td>
<td>393 vs. 393</td>
<td>251 vs. 251</td>
<td>643 vs. 644</td>
</tr>
<tr>
<td>Visitor</td>
<td>370 vs. 372</td>
<td>87 vs. 87</td>
<td>457 vs. 459</td>
</tr>
<tr>
<td>Ward type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ICU wards</td>
<td>5,032 vs. 7,797</td>
<td>3,468 vs. 5,636</td>
<td>8,500 vs. 13,433</td>
</tr>
<tr>
<td>ICU wards</td>
<td>2,981 vs. 4,801</td>
<td>1,475 vs. 2,475</td>
<td>4,456 vs. 7,276</td>
</tr>
<tr>
<td>Department</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obstetrics and gynecology</td>
<td>176 vs. 295</td>
<td>652 vs. 1,162</td>
<td>828 vs. 1,457</td>
</tr>
<tr>
<td>Eye</td>
<td>35 vs. 60</td>
<td>163 vs. 307</td>
<td>198 vs. 367</td>
</tr>
<tr>
<td>Ear Nose Throat</td>
<td>65 vs. 108</td>
<td>136 vs. 256</td>
<td>201 vs. 364</td>
</tr>
<tr>
<td>Pediatrics</td>
<td>873 vs. 1,416</td>
<td>1,134 vs. 1,893</td>
<td>2,007 vs. 3,309</td>
</tr>
<tr>
<td>Medicine</td>
<td>2,478 vs. 3,634</td>
<td>1,508 vs. 2,266</td>
<td>3,986 vs. 5,900</td>
</tr>
<tr>
<td>Surgery</td>
<td>4,386 vs. 7,085</td>
<td>1,350 vs. 2,227</td>
<td>5,736 vs. 9,312</td>
</tr>
</tbody>
</table>
D.5: Descriptive statistics by observed opportunities \([n]\) for characteristics and covariates in the study

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before intervention</th>
<th>After intervention</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 34,430)</td>
<td>%</td>
<td>(n = 22,646)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>7,837</td>
<td>22.76</td>
<td>3,874</td>
</tr>
<tr>
<td>Female</td>
<td>26,593</td>
<td>77.24</td>
<td>18,772</td>
</tr>
<tr>
<td>Type of HCW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctor</td>
<td>1,829</td>
<td>5.31</td>
<td>609</td>
</tr>
<tr>
<td>Registered Nurse</td>
<td>18,702</td>
<td>54.32</td>
<td>12,667</td>
</tr>
<tr>
<td>Technical Nurse</td>
<td>588</td>
<td>1.71</td>
<td>506</td>
</tr>
<tr>
<td>Nursing Assistant</td>
<td>1,659</td>
<td>4.82</td>
<td>1,233</td>
</tr>
<tr>
<td>Nursing Aide</td>
<td>6,557</td>
<td>19.04</td>
<td>4,306</td>
</tr>
<tr>
<td>Worker</td>
<td>2,095</td>
<td>6.08</td>
<td>1,816</td>
</tr>
<tr>
<td>Medical Student</td>
<td>418</td>
<td>1.21</td>
<td>101</td>
</tr>
<tr>
<td>Nursing Student</td>
<td>1,361</td>
<td>3.95</td>
<td>1,084</td>
</tr>
<tr>
<td>Visitor</td>
<td>1,221</td>
<td>3.55</td>
<td>324</td>
</tr>
<tr>
<td>Ward type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ICU wards</td>
<td>22,336</td>
<td>64.87</td>
<td>16,089</td>
</tr>
<tr>
<td>ICU wards</td>
<td>12,094</td>
<td>35.13</td>
<td>6,557</td>
</tr>
</tbody>
</table>
D.5: Descriptive statistics by observed opportunities [n] for characteristics and covariates in the study (cont.)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before intervention</th>
<th>After intervention</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 34,430</td>
<td>%</td>
<td>n = 22,646</td>
</tr>
<tr>
<td>Department</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obstetrics and gynecology</td>
<td>683</td>
<td>1.98</td>
<td>2,760</td>
</tr>
<tr>
<td>Eye</td>
<td>175</td>
<td>0.51</td>
<td>786</td>
</tr>
<tr>
<td>Ear Nose Throat</td>
<td>243</td>
<td>0.71</td>
<td>585</td>
</tr>
<tr>
<td>Paediatrics</td>
<td>3,418</td>
<td>9.93</td>
<td>4,804</td>
</tr>
<tr>
<td>Medicine</td>
<td>11,071</td>
<td>32.16</td>
<td>7,449</td>
</tr>
<tr>
<td>Surgery</td>
<td>18,840</td>
<td>54.72</td>
<td>6,262</td>
</tr>
<tr>
<td>Indication for performing hand hygiene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before touching a patient</td>
<td>7,904</td>
<td>22.96</td>
<td>4,802</td>
</tr>
<tr>
<td>After touching a patient</td>
<td>7,781</td>
<td>22.6</td>
<td>4,697</td>
</tr>
<tr>
<td>Before clean/aseptic procedures</td>
<td>4,266</td>
<td>12.39</td>
<td>2,604</td>
</tr>
<tr>
<td>After body fluid exposure/risk</td>
<td>4,780</td>
<td>13.88</td>
<td>2,668</td>
</tr>
<tr>
<td>After touching patient surroundings</td>
<td>9,699</td>
<td>28.17</td>
<td>7,875</td>
</tr>
</tbody>
</table>
## D.6: Summary of characteristics of all study wards

<table>
<thead>
<tr>
<th>Ward</th>
<th>Department*</th>
<th>ICU</th>
<th>No. of Permanent staff</th>
<th>No. of Visitors</th>
<th>Before intervention</th>
<th>No. of HCW observed</th>
<th>No. of opportunities</th>
<th>After intervention</th>
<th>No. of HCW observed</th>
<th>No. of opportunities</th>
<th>Overall</th>
<th>No. of HCW observed</th>
<th>No. of opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Obst</td>
<td>no</td>
<td>22</td>
<td>38</td>
<td>18</td>
<td>108</td>
<td>269</td>
<td>56</td>
<td>252</td>
<td>665</td>
<td>74</td>
<td>360</td>
<td>934</td>
</tr>
<tr>
<td>2</td>
<td>Obst</td>
<td>no</td>
<td>24</td>
<td>45</td>
<td>5</td>
<td>42</td>
<td>68</td>
<td>69</td>
<td>325</td>
<td>806</td>
<td>74</td>
<td>367</td>
<td>874</td>
</tr>
<tr>
<td>3</td>
<td>Obst</td>
<td>no</td>
<td>20</td>
<td>18</td>
<td>5</td>
<td>31</td>
<td>63</td>
<td>67</td>
<td>339</td>
<td>741</td>
<td>72</td>
<td>370</td>
<td>804</td>
</tr>
<tr>
<td>4</td>
<td>Obst</td>
<td>no</td>
<td>21</td>
<td>28</td>
<td>20</td>
<td>114</td>
<td>283</td>
<td>54</td>
<td>246</td>
<td>548</td>
<td>74</td>
<td>360</td>
<td>831</td>
</tr>
<tr>
<td>5</td>
<td>Obst</td>
<td>no</td>
<td>22</td>
<td>33</td>
<td>62</td>
<td>310</td>
<td>1,000</td>
<td>12</td>
<td>41</td>
<td>117</td>
<td>74</td>
<td>351</td>
<td>1,117</td>
</tr>
<tr>
<td>6</td>
<td>Obst</td>
<td>no</td>
<td>26</td>
<td>33</td>
<td>8</td>
<td>43</td>
<td>149</td>
<td>66</td>
<td>302</td>
<td>937</td>
<td>74</td>
<td>345</td>
<td>1,086</td>
</tr>
<tr>
<td>7</td>
<td>Obst</td>
<td>no</td>
<td>26</td>
<td>36</td>
<td>16</td>
<td>92</td>
<td>220</td>
<td>58</td>
<td>259</td>
<td>665</td>
<td>74</td>
<td>351</td>
<td>885</td>
</tr>
<tr>
<td>8</td>
<td>Obst</td>
<td>no</td>
<td>23</td>
<td>63</td>
<td>13</td>
<td>87</td>
<td>184</td>
<td>60</td>
<td>306</td>
<td>671</td>
<td>73</td>
<td>393</td>
<td>855</td>
</tr>
<tr>
<td>9</td>
<td>Obst</td>
<td>no</td>
<td>22</td>
<td>29</td>
<td>10</td>
<td>58</td>
<td>139</td>
<td>64</td>
<td>293</td>
<td>778</td>
<td>74</td>
<td>351</td>
<td>917</td>
</tr>
<tr>
<td>10</td>
<td>Eye</td>
<td>no</td>
<td>25</td>
<td>20</td>
<td>11</td>
<td>60</td>
<td>175</td>
<td>63</td>
<td>307</td>
<td>786</td>
<td>74</td>
<td>367</td>
<td>961</td>
</tr>
</tbody>
</table>

*Note: Obst= Obstetrics and gynecology; ENT= Ear Nose Throat; Paed= Paediatrics; Med= Medicine; Surg= Surgery
D.6: Summary of characteristics of all study wards (cont.)

<table>
<thead>
<tr>
<th>Ward</th>
<th>Department*</th>
<th>ICU</th>
<th>No. of Permanent staff</th>
<th>No. of Visitors</th>
<th>Before intervention</th>
<th>After intervention</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No. of Observed HCW observed</td>
<td>No. of HCW opportunities</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>ENT</td>
<td>no</td>
<td>25</td>
<td>25</td>
<td>108</td>
<td>243</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
<td>256</td>
<td>585</td>
</tr>
<tr>
<td>12</td>
<td>Paed</td>
<td>yes</td>
<td>26</td>
<td>18</td>
<td>65</td>
<td>353</td>
<td>189</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td>42</td>
<td>61</td>
</tr>
<tr>
<td>13</td>
<td>Paed</td>
<td>yes</td>
<td>26</td>
<td>12</td>
<td>20</td>
<td>108</td>
<td>707</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
<td>267</td>
<td>512</td>
</tr>
<tr>
<td>14</td>
<td>Paed</td>
<td>yes</td>
<td>27</td>
<td>33</td>
<td>7</td>
<td>47</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>67</td>
<td>335</td>
<td>964</td>
</tr>
<tr>
<td>15</td>
<td>Paed</td>
<td>yes</td>
<td>31</td>
<td>31</td>
<td>64</td>
<td>318</td>
<td>735</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>48</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>74</td>
<td>366</td>
<td>834</td>
</tr>
<tr>
<td>16</td>
<td>Med</td>
<td>no</td>
<td>33</td>
<td>50</td>
<td>50</td>
<td>295</td>
<td>1,115</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24</td>
<td>121</td>
<td>595</td>
</tr>
<tr>
<td>17</td>
<td>Med</td>
<td>no</td>
<td>37</td>
<td>55</td>
<td>23</td>
<td>149</td>
<td>570</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>51</td>
<td>217</td>
<td>880</td>
</tr>
<tr>
<td>18</td>
<td>Med</td>
<td>no</td>
<td>32</td>
<td>47</td>
<td>64</td>
<td>341</td>
<td>1,276</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>33</td>
<td>86</td>
</tr>
<tr>
<td>19</td>
<td>Med</td>
<td>no</td>
<td>35</td>
<td>47</td>
<td>33</td>
<td>199</td>
<td>825</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>41</td>
<td>167</td>
<td>838</td>
</tr>
<tr>
<td>20</td>
<td>Med</td>
<td>no</td>
<td>36</td>
<td>64</td>
<td>65</td>
<td>348</td>
<td>1,382</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>37</td>
<td>165</td>
</tr>
</tbody>
</table>

*Note: Obst= Obstetrics and gynecology; ENT= Ear Nose Throat; Paed= Paediatrics; Med= Medicine; Surg= Surgery
D.6: Summary of characteristics of all study wards (cont.)

<table>
<thead>
<tr>
<th>Ward</th>
<th>Department*</th>
<th>ICU</th>
<th>No. of Permanent staff</th>
<th>No. of Visitors</th>
<th>Before intervention</th>
<th>After intervention</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No. of HCW observed</td>
<td>No. of opportunities</td>
<td>No. of HCW observed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No. of HCW observed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Med</td>
<td>no</td>
<td>42</td>
<td>43</td>
<td>44</td>
<td>251</td>
<td>967</td>
</tr>
<tr>
<td>22</td>
<td>Med</td>
<td>no</td>
<td>27</td>
<td>23</td>
<td>20</td>
<td>119</td>
<td>257</td>
</tr>
<tr>
<td>23</td>
<td>Med</td>
<td>yes</td>
<td>28</td>
<td>43</td>
<td>33</td>
<td>208</td>
<td>531</td>
</tr>
<tr>
<td>24</td>
<td>Med</td>
<td>yes</td>
<td>31</td>
<td>39</td>
<td>24</td>
<td>162</td>
<td>420</td>
</tr>
<tr>
<td>25</td>
<td>Med</td>
<td>yes</td>
<td>30</td>
<td>36</td>
<td>23</td>
<td>146</td>
<td>427</td>
</tr>
<tr>
<td>26</td>
<td>Med</td>
<td>yes</td>
<td>30</td>
<td>37</td>
<td>23</td>
<td>148</td>
<td>354</td>
</tr>
<tr>
<td>27</td>
<td>Med</td>
<td>yes</td>
<td>33</td>
<td>31</td>
<td>65</td>
<td>330</td>
<td>841</td>
</tr>
<tr>
<td>28</td>
<td>Med</td>
<td>no</td>
<td>36</td>
<td>13</td>
<td>23</td>
<td>139</td>
<td>303</td>
</tr>
<tr>
<td>29</td>
<td>Med</td>
<td>no</td>
<td>24</td>
<td>17</td>
<td>65</td>
<td>318</td>
<td>790</td>
</tr>
<tr>
<td>30</td>
<td>Med</td>
<td>yes</td>
<td>27</td>
<td>17</td>
<td>31</td>
<td>178</td>
<td>350</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No. of HCW observed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,530</td>
<td>1,742</td>
<td>2,367</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No. of HCW observed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,839</td>
<td>8,111</td>
<td>22,646</td>
</tr>
</tbody>
</table>

*Note: Obst= Obstetrics and gynecology; ENT= Ear Nose Throat; Paed= Paediatrics; Med= Medicine; Surg= Surgery
D.6: Summary of characteristics of all study wards (cont.)

<table>
<thead>
<tr>
<th>Ward</th>
<th>Department*</th>
<th>ICU</th>
<th>No. of Permanent staff</th>
<th>No. of Visitors</th>
<th>No. of Observed sessions</th>
<th>No. of HCW observed</th>
<th>No. of opportunities</th>
<th>No. of HCW observed</th>
<th>No. of opportunities</th>
<th>No. of Observed sessions</th>
<th>No. of HCW observed</th>
<th>No. of opportunities</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>Med</td>
<td>yes</td>
<td>29</td>
<td>12</td>
<td>64</td>
<td>303</td>
<td>663</td>
<td>9</td>
<td>35</td>
<td>78</td>
<td>73</td>
<td>338</td>
<td>741</td>
</tr>
<tr>
<td>32</td>
<td>Surg</td>
<td>no</td>
<td>25</td>
<td>35</td>
<td>45</td>
<td>253</td>
<td>679</td>
<td>29</td>
<td>118</td>
<td>398</td>
<td>74</td>
<td>371</td>
<td>1,077</td>
</tr>
<tr>
<td>33</td>
<td>Surg</td>
<td>no</td>
<td>25</td>
<td>43</td>
<td>37</td>
<td>217</td>
<td>684</td>
<td>37</td>
<td>157</td>
<td>440</td>
<td>74</td>
<td>374</td>
<td>1,124</td>
</tr>
<tr>
<td>34</td>
<td>Surg</td>
<td>no</td>
<td>17</td>
<td>29</td>
<td>65</td>
<td>324</td>
<td>887</td>
<td>8</td>
<td>33</td>
<td>82</td>
<td>73</td>
<td>357</td>
<td>969</td>
</tr>
<tr>
<td>35</td>
<td>Surg</td>
<td>no</td>
<td>19</td>
<td>33</td>
<td>44</td>
<td>229</td>
<td>569</td>
<td>30</td>
<td>124</td>
<td>363</td>
<td>74</td>
<td>353</td>
<td>932</td>
</tr>
<tr>
<td>36</td>
<td>Surg</td>
<td>no</td>
<td>20</td>
<td>32</td>
<td>37</td>
<td>201</td>
<td>519</td>
<td>37</td>
<td>151</td>
<td>462</td>
<td>74</td>
<td>352</td>
<td>981</td>
</tr>
<tr>
<td>37</td>
<td>Surg</td>
<td>no</td>
<td>21</td>
<td>45</td>
<td>33</td>
<td>206</td>
<td>487</td>
<td>41</td>
<td>171</td>
<td>496</td>
<td>74</td>
<td>377</td>
<td>983</td>
</tr>
<tr>
<td>38</td>
<td>Surg</td>
<td>no</td>
<td>23</td>
<td>20</td>
<td>62</td>
<td>314</td>
<td>634</td>
<td>12</td>
<td>47</td>
<td>125</td>
<td>74</td>
<td>361</td>
<td>759</td>
</tr>
<tr>
<td>39</td>
<td>Surg</td>
<td>no</td>
<td>24</td>
<td>27</td>
<td>64</td>
<td>308</td>
<td>927</td>
<td>10</td>
<td>35</td>
<td>131</td>
<td>74</td>
<td>343</td>
<td>1,058</td>
</tr>
<tr>
<td>40</td>
<td>Surg</td>
<td>no</td>
<td>23</td>
<td>20</td>
<td>65</td>
<td>334</td>
<td>763</td>
<td>9</td>
<td>32</td>
<td>91</td>
<td>74</td>
<td>366</td>
<td>854</td>
</tr>
</tbody>
</table>

*Note: Obst= Obstetrics and gynecology; ENT= Ear Nose Throat; Paed= Paediatrics; Med= Medicine; Surg= Surgery
### D.6: Summary of characteristics of all study wards (cont.)

<table>
<thead>
<tr>
<th>Ward</th>
<th>Department*</th>
<th>ICU</th>
<th>No. of Permanent staff</th>
<th>No. of Visitors</th>
<th>No. of Observed sessions</th>
<th>No. of HCW observed</th>
<th>No. of opportunities</th>
<th>No. of Observed sessions</th>
<th>No. of HCW observed</th>
<th>No. of opportunities</th>
<th>No. of Observed sessions</th>
<th>No. of HCW observed</th>
<th>No. of opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>Surg</td>
<td>no</td>
<td>27</td>
<td>17</td>
<td>61</td>
<td>311</td>
<td>992</td>
<td>13</td>
<td>49</td>
<td>144</td>
<td>74</td>
<td>360</td>
<td>1,136</td>
</tr>
<tr>
<td>42</td>
<td>Surg</td>
<td>no</td>
<td>28</td>
<td>20</td>
<td>65</td>
<td>302</td>
<td>946</td>
<td>9</td>
<td>34</td>
<td>78</td>
<td>74</td>
<td>336</td>
<td>1,024</td>
</tr>
<tr>
<td>43</td>
<td>Surg</td>
<td>no</td>
<td>21</td>
<td>30</td>
<td>47</td>
<td>258</td>
<td>625</td>
<td>27</td>
<td>112</td>
<td>324</td>
<td>74</td>
<td>370</td>
<td>949</td>
</tr>
<tr>
<td>44</td>
<td>Surg</td>
<td>no</td>
<td>22</td>
<td>28</td>
<td>63</td>
<td>312</td>
<td>756</td>
<td>11</td>
<td>49</td>
<td>117</td>
<td>74</td>
<td>361</td>
<td>873</td>
</tr>
<tr>
<td>45</td>
<td>Surg</td>
<td>no</td>
<td>26</td>
<td>51</td>
<td>45</td>
<td>247</td>
<td>600</td>
<td>29</td>
<td>128</td>
<td>327</td>
<td>74</td>
<td>375</td>
<td>927</td>
</tr>
<tr>
<td>46</td>
<td>Surg</td>
<td>no</td>
<td>27</td>
<td>37</td>
<td>44</td>
<td>211</td>
<td>540</td>
<td>30</td>
<td>128</td>
<td>358</td>
<td>74</td>
<td>339</td>
<td>898</td>
</tr>
<tr>
<td>47</td>
<td>Surg</td>
<td>no</td>
<td>25</td>
<td>47</td>
<td>63</td>
<td>329</td>
<td>872</td>
<td>11</td>
<td>44</td>
<td>128</td>
<td>74</td>
<td>373</td>
<td>1,000</td>
</tr>
<tr>
<td>48</td>
<td>Surg</td>
<td>yes</td>
<td>31</td>
<td>30</td>
<td>49</td>
<td>268</td>
<td>719</td>
<td>25</td>
<td>91</td>
<td>241</td>
<td>74</td>
<td>359</td>
<td>960</td>
</tr>
<tr>
<td>49</td>
<td>Surg</td>
<td>yes</td>
<td>32</td>
<td>22</td>
<td>64</td>
<td>313</td>
<td>1,030</td>
<td>9</td>
<td>36</td>
<td>91</td>
<td>73</td>
<td>349</td>
<td>1,121</td>
</tr>
<tr>
<td>50</td>
<td>Surg</td>
<td>yes</td>
<td>31</td>
<td>28</td>
<td>43</td>
<td>240</td>
<td>584</td>
<td>31</td>
<td>124</td>
<td>314</td>
<td>74</td>
<td>364</td>
<td>898</td>
</tr>
</tbody>
</table>

*Note: Obst= Obstetrics and gynecology; ENT= Ear Nose Throat; Paed= Paediatrics; Med= Medicine; Surg= Surgery*
D.6: Summary of characteristics of all study wards (cont.)

<table>
<thead>
<tr>
<th>Ward</th>
<th>Department*</th>
<th>ICU</th>
<th>No. of Permanent staff</th>
<th>No. of Visitors Before intervention</th>
<th>No. of HCW observed Before intervention</th>
<th>No. of observed opportunities Before intervention</th>
<th>No. of HCW observed After intervention</th>
<th>No. of observed opportunities After intervention</th>
<th>No. of HCW observed Overall</th>
<th>No. of observed opportunities Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>51</td>
<td>Surg</td>
<td>yes</td>
<td>26</td>
<td>24</td>
<td>37</td>
<td>207</td>
<td>504</td>
<td>37</td>
<td>150</td>
<td>395</td>
</tr>
<tr>
<td>52</td>
<td>Surg</td>
<td>yes</td>
<td>32</td>
<td>9</td>
<td>47</td>
<td>271</td>
<td>601</td>
<td>26</td>
<td>104</td>
<td>272</td>
</tr>
<tr>
<td>53</td>
<td>Surg</td>
<td>yes</td>
<td>25</td>
<td>6</td>
<td>63</td>
<td>284</td>
<td>701</td>
<td>11</td>
<td>48</td>
<td>90</td>
</tr>
<tr>
<td>54</td>
<td>Surg</td>
<td>yes</td>
<td>30</td>
<td>28</td>
<td>63</td>
<td>324</td>
<td>925</td>
<td>11</td>
<td>36</td>
<td>150</td>
</tr>
<tr>
<td>56</td>
<td>Surg</td>
<td>yes</td>
<td>26</td>
<td>14</td>
<td>61</td>
<td>297</td>
<td>892</td>
<td>12</td>
<td>46</td>
<td>150</td>
</tr>
<tr>
<td>57</td>
<td>Surg</td>
<td>yes</td>
<td>23</td>
<td>9</td>
<td>62</td>
<td>296</td>
<td>826</td>
<td>12</td>
<td>59</td>
<td>131</td>
</tr>
<tr>
<td>58</td>
<td>Surg</td>
<td>no</td>
<td>25</td>
<td>22</td>
<td>44</td>
<td>229</td>
<td>578</td>
<td>30</td>
<td>121</td>
<td>364</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: Obst= Obstetrics and gynecology; ENT= Ear Nose Throat; Paed= Paediatrics; Med=Medicine; Surg= Surgery

*No. of HCW observed: Number of healthcare workers observed during sessions.
*No. of opportunities: Number of opportunities for interaction observed.

Total: 1,530, 1,742, 2,367, 12,598, 34,430, 1,839, 8,111, 22,646, 4,206, 20,709, 57,076.
### D.7: Hand hygiene compliance of study wards

<table>
<thead>
<tr>
<th>Ward</th>
<th>Before intervention</th>
<th>After intervention</th>
<th>Overall</th>
<th>% Improvements</th>
<th>Per-protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obs     Mean  Std. Dev. Min Max</td>
<td>Obs     Mean  Std. Dev. Min Max</td>
<td>Obs     Mean  Std. Dev. Min Max</td>
<td>% Improvements</td>
<td>Per-protocol</td>
</tr>
<tr>
<td>1</td>
<td>269 4.46 5.78 0 20.00</td>
<td>665 9.32 13.31 0 80.00</td>
<td>934 7.92 11.86 0 80.00</td>
<td>4.86 ↑↑</td>
<td>no</td>
</tr>
<tr>
<td>2</td>
<td>68 4.41 2.77 0 7.14</td>
<td>806 7.69 10.49 0 44.44</td>
<td>874 7.44 10.15 0 44.44</td>
<td>3.28 ↑</td>
<td>yes</td>
</tr>
<tr>
<td>3</td>
<td>63 0.00 0.00 0 0.00</td>
<td>741 6.21 8.70 0 50.00</td>
<td>804 5.72 8.52 0 50.00</td>
<td>6.21 ↑↑↑</td>
<td>yes</td>
</tr>
<tr>
<td>4</td>
<td>283 2.12 3.98 0 14.29</td>
<td>548 3.83 6.25 0 28.57</td>
<td>831 3.25 5.64 0 28.57</td>
<td>1.71 ↑</td>
<td>yes</td>
</tr>
<tr>
<td>5</td>
<td>1,000 10.80 10.74 0 47.37</td>
<td>117 8.55 14.65 0 44.44</td>
<td>1,117 10.56 11.23 0 47.37</td>
<td>-2.25 ↓</td>
<td>no</td>
</tr>
<tr>
<td>6</td>
<td>149 6.71 16.88 0 52.94</td>
<td>937 15.26 17.61 0 80.00</td>
<td>1,086 14.09 17.75 0 80.00</td>
<td>8.55 ↑↑</td>
<td>yes</td>
</tr>
<tr>
<td>7</td>
<td>220 19.09 26.22 0 100.00</td>
<td>665 7.37 9.33 0 35.71</td>
<td>885 10.28 16.17 0 100.00</td>
<td>-11.72 ↓</td>
<td>yes</td>
</tr>
<tr>
<td>8</td>
<td>184 5.43 7.80 0 23.08</td>
<td>671 5.81 8.15 0 30.00</td>
<td>855 5.73 8.07 0 30.00</td>
<td>0.38 ↑</td>
<td>yes</td>
</tr>
<tr>
<td>9</td>
<td>139 13.67 17.59 0 50.00</td>
<td>778 11.44 16.05 0 83.33</td>
<td>917 11.78 16.30 0 83.33</td>
<td>-2.23 ↓</td>
<td>yes</td>
</tr>
<tr>
<td>10</td>
<td>175 31.43 26.12 0 83.33</td>
<td>786 29.01 24.17 0 100.00</td>
<td>961 29.45 24.54 0 100.00</td>
<td>-2.42 ↓</td>
<td>yes</td>
</tr>
<tr>
<td>11</td>
<td>243 8.23 13.61 0 58.33</td>
<td>585 13.85 18.23 0 100.00</td>
<td>828 12.20 17.19 0 100.00</td>
<td>5.62 ↑</td>
<td>yes</td>
</tr>
<tr>
<td>12</td>
<td>707 29.56 21.22 0 90.00</td>
<td>61 39.34 13.59 20 60.00</td>
<td>768 30.34 20.88 0 90.00</td>
<td>9.78 ↑</td>
<td>no</td>
</tr>
<tr>
<td>13</td>
<td>189 26.46 26.17 0 100.00</td>
<td>512 30.86 20.83 0 100.00</td>
<td>701 29.67 22.46 0 100.00</td>
<td>4.40 ↑</td>
<td>yes</td>
</tr>
<tr>
<td>14</td>
<td>95 13.68 18.48 0 63.64</td>
<td>964 17.95 14.39 0 53.85</td>
<td>1,059 17.56 14.84 0 63.64</td>
<td>4.26 ↑</td>
<td>yes</td>
</tr>
<tr>
<td>15</td>
<td>735 18.37 17.49 0 70.00</td>
<td>99 14.14 9.28 0 28.57</td>
<td>834 17.87 16.78 0 70.00</td>
<td>-4.23 ↓</td>
<td>no</td>
</tr>
</tbody>
</table>
### D.7: Hand hygiene compliance of study wards (cont.)

<table>
<thead>
<tr>
<th>Ward</th>
<th>Before intervention</th>
<th>After intervention</th>
<th>Overall</th>
<th>% Improvements</th>
<th>Per-protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obs</td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>16</td>
<td>1,115</td>
<td>4.66</td>
<td>5.87</td>
<td>0</td>
<td>25.00</td>
</tr>
<tr>
<td>17</td>
<td>570</td>
<td>3.33</td>
<td>4.60</td>
<td>0</td>
<td>20.00</td>
</tr>
<tr>
<td>18</td>
<td>1,276</td>
<td>5.88</td>
<td>8.38</td>
<td>0</td>
<td>45.00</td>
</tr>
<tr>
<td>19</td>
<td>825</td>
<td>4.36</td>
<td>6.02</td>
<td>0</td>
<td>23.81</td>
</tr>
<tr>
<td>20</td>
<td>1,382</td>
<td>3.33</td>
<td>6.15</td>
<td>0</td>
<td>40.00</td>
</tr>
<tr>
<td>21</td>
<td>967</td>
<td>3.31</td>
<td>4.72</td>
<td>0</td>
<td>28.57</td>
</tr>
<tr>
<td>22</td>
<td>257</td>
<td>6.23</td>
<td>6.92</td>
<td>0</td>
<td>21.43</td>
</tr>
<tr>
<td>23</td>
<td>531</td>
<td>16.95</td>
<td>17.23</td>
<td>0</td>
<td>91.67</td>
</tr>
<tr>
<td>24</td>
<td>420</td>
<td>9.05</td>
<td>8.79</td>
<td>0</td>
<td>41.18</td>
</tr>
<tr>
<td>25</td>
<td>427</td>
<td>13.35</td>
<td>18.17</td>
<td>0</td>
<td>59.09</td>
</tr>
<tr>
<td>26</td>
<td>354</td>
<td>13.28</td>
<td>16.61</td>
<td>0</td>
<td>64.29</td>
</tr>
<tr>
<td>27</td>
<td>841</td>
<td>15.10</td>
<td>13.62</td>
<td>0</td>
<td>76.92</td>
</tr>
<tr>
<td>28</td>
<td>303</td>
<td>5.28</td>
<td>11.17</td>
<td>0</td>
<td>66.67</td>
</tr>
<tr>
<td>29</td>
<td>790</td>
<td>8.73</td>
<td>9.48</td>
<td>0</td>
<td>40.00</td>
</tr>
<tr>
<td>30</td>
<td>350</td>
<td>2.86</td>
<td>5.10</td>
<td>0</td>
<td>20.00</td>
</tr>
</tbody>
</table>
### D.7: Hand hygiene compliance of study wards (cont.)

<table>
<thead>
<tr>
<th>Ward</th>
<th>Before intervention</th>
<th>After intervention</th>
<th>Overall</th>
<th>% Improvements</th>
<th>Per-protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obs</td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>31</td>
<td>663</td>
<td>12.97</td>
<td>14.34</td>
<td>0</td>
<td>62.50</td>
</tr>
<tr>
<td>32</td>
<td>679</td>
<td>4.12</td>
<td>9.18</td>
<td>0</td>
<td>50.00</td>
</tr>
<tr>
<td>33</td>
<td>684</td>
<td>4.24</td>
<td>6.93</td>
<td>0</td>
<td>33.33</td>
</tr>
<tr>
<td>34</td>
<td>887</td>
<td>7.10</td>
<td>13.63</td>
<td>0</td>
<td>76.92</td>
</tr>
<tr>
<td>35</td>
<td>569</td>
<td>10.54</td>
<td>9.92</td>
<td>0</td>
<td>33.33</td>
</tr>
<tr>
<td>36</td>
<td>519</td>
<td>10.40</td>
<td>12.46</td>
<td>0</td>
<td>70.00</td>
</tr>
<tr>
<td>37</td>
<td>487</td>
<td>7.80</td>
<td>10.72</td>
<td>0</td>
<td>54.55</td>
</tr>
<tr>
<td>38</td>
<td>634</td>
<td>7.10</td>
<td>10.62</td>
<td>0</td>
<td>50.00</td>
</tr>
<tr>
<td>39</td>
<td>927</td>
<td>6.80</td>
<td>9.38</td>
<td>0</td>
<td>43.48</td>
</tr>
<tr>
<td>40</td>
<td>763</td>
<td>3.15</td>
<td>6.30</td>
<td>0</td>
<td>28.57</td>
</tr>
<tr>
<td>41</td>
<td>992</td>
<td>8.97</td>
<td>11.51</td>
<td>0</td>
<td>50.00</td>
</tr>
<tr>
<td>42</td>
<td>946</td>
<td>7.93</td>
<td>11.89</td>
<td>0</td>
<td>50.00</td>
</tr>
<tr>
<td>43</td>
<td>625</td>
<td>12.48</td>
<td>13.63</td>
<td>0</td>
<td>42.86</td>
</tr>
<tr>
<td>44</td>
<td>756</td>
<td>5.56</td>
<td>8.82</td>
<td>0</td>
<td>50.00</td>
</tr>
<tr>
<td>45</td>
<td>600</td>
<td>5.17</td>
<td>8.20</td>
<td>0</td>
<td>38.46</td>
</tr>
</tbody>
</table>
D.7: Hand hygiene compliance of study wards (cont.)

<table>
<thead>
<tr>
<th>Ward</th>
<th>Before intervention</th>
<th>After intervention</th>
<th>Overall</th>
<th>% Improvements</th>
<th>Per-protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obs</td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>46</td>
<td>540</td>
<td>5.74</td>
<td>8.88</td>
<td>0</td>
<td>29.41</td>
</tr>
<tr>
<td>47</td>
<td>872</td>
<td>8.37</td>
<td>10.48</td>
<td>0</td>
<td>50.00</td>
</tr>
<tr>
<td>48</td>
<td>719</td>
<td>17.80</td>
<td>14.96</td>
<td>0</td>
<td>60.00</td>
</tr>
<tr>
<td>49</td>
<td>1,030</td>
<td>14.95</td>
<td>16.78</td>
<td>0</td>
<td>80.00</td>
</tr>
<tr>
<td>50</td>
<td>584</td>
<td>17.64</td>
<td>16.70</td>
<td>0</td>
<td>66.67</td>
</tr>
<tr>
<td>51</td>
<td>504</td>
<td>18.45</td>
<td>20.62</td>
<td>0</td>
<td>78.57</td>
</tr>
<tr>
<td>52</td>
<td>601</td>
<td>20.13</td>
<td>19.96</td>
<td>0</td>
<td>78.95</td>
</tr>
<tr>
<td>53</td>
<td>701</td>
<td>11.41</td>
<td>12.96</td>
<td>0</td>
<td>50.00</td>
</tr>
<tr>
<td>54</td>
<td>925</td>
<td>11.57</td>
<td>15.36</td>
<td>0</td>
<td>68.75</td>
</tr>
<tr>
<td>55</td>
<td>892</td>
<td>15.70</td>
<td>15.97</td>
<td>0</td>
<td>75.00</td>
</tr>
<tr>
<td>56</td>
<td>826</td>
<td>23.12</td>
<td>21.08</td>
<td>0</td>
<td>90.00</td>
</tr>
<tr>
<td>57</td>
<td>578</td>
<td>4.84</td>
<td>6.11</td>
<td>0</td>
<td>20.00</td>
</tr>
<tr>
<td>58</td>
<td>725</td>
<td>7.89</td>
<td>8.67</td>
<td>0</td>
<td>30.41</td>
</tr>
</tbody>
</table>
### D.8: Descriptive statistics for characteristics and covariates in the study by observed HCWs [n]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before intervention (n = 11,112)</th>
<th>After intervention (n = 7,289)</th>
<th>Overall (n = 18,401)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2,934</td>
<td>1,537</td>
<td>4,471</td>
</tr>
<tr>
<td>Female</td>
<td>8,178</td>
<td>5,752</td>
<td>13,930</td>
</tr>
<tr>
<td>Type of HCWs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctor</td>
<td>491</td>
<td>139</td>
<td>630</td>
</tr>
<tr>
<td>Registered Nurse</td>
<td>5,512</td>
<td>3,666</td>
<td>9,178</td>
</tr>
<tr>
<td>Technical Nurse</td>
<td>194</td>
<td>223</td>
<td>417</td>
</tr>
<tr>
<td>Nursing Assistant</td>
<td>473</td>
<td>314</td>
<td>787</td>
</tr>
<tr>
<td>Nursing Aide</td>
<td>2,382</td>
<td>1,527</td>
<td>3,909</td>
</tr>
<tr>
<td>Worker</td>
<td>1,177</td>
<td>1,053</td>
<td>2,230</td>
</tr>
<tr>
<td>Medical Student</td>
<td>118</td>
<td>29</td>
<td>147</td>
</tr>
<tr>
<td>Nursing Student</td>
<td>393</td>
<td>251</td>
<td>644</td>
</tr>
<tr>
<td>Visitor</td>
<td>372</td>
<td>87</td>
<td>459</td>
</tr>
<tr>
<td>Ward type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ICU wards</td>
<td>6,991</td>
<td>5,140</td>
<td>12,131</td>
</tr>
<tr>
<td>ICU wards</td>
<td>4,121</td>
<td>2,149</td>
<td>6,270</td>
</tr>
<tr>
<td>Department</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obstetrics and gynecology</td>
<td>261</td>
<td>1,028</td>
<td>1,289</td>
</tr>
<tr>
<td>Eye</td>
<td>54</td>
<td>274</td>
<td>328</td>
</tr>
<tr>
<td>Ear Nose Throat</td>
<td>99</td>
<td>238</td>
<td>337</td>
</tr>
<tr>
<td>Pediatrics</td>
<td>1,193</td>
<td>1,623</td>
<td>2,816</td>
</tr>
<tr>
<td>Medicine</td>
<td>3,218</td>
<td>2,068</td>
<td>5,286</td>
</tr>
<tr>
<td>Surgery</td>
<td>6,287</td>
<td>2,058</td>
<td>8,345</td>
</tr>
</tbody>
</table>
### D.9: Characteristic of hand hygiene compliance by the variables during before intervention

<table>
<thead>
<tr>
<th>Variables</th>
<th>Before intervention (n = 34,430)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean</td>
<td>SD</td>
<td>Min</td>
<td>Max</td>
<td>Skewness</td>
<td>Kurtosis</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>34,430</td>
<td>10.10</td>
<td>20.85</td>
<td>0</td>
<td>100</td>
<td>2.61</td>
<td>10.01</td>
<td></td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>7,837</td>
<td>5.33</td>
<td>15.16</td>
<td>0</td>
<td>100</td>
<td>3.78</td>
<td>19.43</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>26,593</td>
<td>11.50</td>
<td>22.06</td>
<td>0</td>
<td>100</td>
<td>2.40</td>
<td>8.71</td>
<td></td>
</tr>
<tr>
<td><strong>Type of HCW</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctor</td>
<td>1,829</td>
<td>5.41</td>
<td>15.09</td>
<td>0</td>
<td>100</td>
<td>3.37</td>
<td>15.53</td>
<td></td>
</tr>
<tr>
<td>Registered Nurse</td>
<td>18,702</td>
<td>14.56</td>
<td>24.38</td>
<td>0</td>
<td>100</td>
<td>2.06</td>
<td>6.86</td>
<td></td>
</tr>
<tr>
<td>Technical Nurse</td>
<td>588</td>
<td>12.41</td>
<td>22.36</td>
<td>0</td>
<td>100</td>
<td>2.18</td>
<td>7.66</td>
<td></td>
</tr>
<tr>
<td>Nursing Assistant</td>
<td>1,659</td>
<td>5.97</td>
<td>15.57</td>
<td>0</td>
<td>100</td>
<td>3.42</td>
<td>16.54</td>
<td></td>
</tr>
<tr>
<td>Nursing Aide</td>
<td>6,557</td>
<td>4.12</td>
<td>12.48</td>
<td>0</td>
<td>100</td>
<td>3.99</td>
<td>21.43</td>
<td></td>
</tr>
<tr>
<td>Worker</td>
<td>2,095</td>
<td>3.96</td>
<td>12.65</td>
<td>0</td>
<td>100</td>
<td>4.59</td>
<td>28.14</td>
<td></td>
</tr>
<tr>
<td>Medical Student</td>
<td>418</td>
<td>2.87</td>
<td>10.97</td>
<td>0</td>
<td>75</td>
<td>4.51</td>
<td>24.77</td>
<td></td>
</tr>
<tr>
<td>Nursing Student</td>
<td>1,361</td>
<td>5.44</td>
<td>15.52</td>
<td>0</td>
<td>100</td>
<td>3.55</td>
<td>17.32</td>
<td></td>
</tr>
<tr>
<td>Visitor</td>
<td>1,221</td>
<td>3.52</td>
<td>11.11</td>
<td>0</td>
<td>100</td>
<td>3.42</td>
<td>15.44</td>
<td></td>
</tr>
</tbody>
</table>
D.9: Characteristic of hand hygiene compliance by the variables during before intervention (cont.)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Before intervention (n = 34,430)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean</td>
<td>SD</td>
<td>Min</td>
<td>Max</td>
<td>Skewness</td>
<td>Kurtosis</td>
</tr>
<tr>
<td>Ward type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ICU wards</td>
<td>22,336</td>
<td>6.70</td>
<td>16.75</td>
<td>0</td>
<td>100</td>
<td>3.39</td>
<td>16.07</td>
</tr>
<tr>
<td>ICU wards</td>
<td>12,094</td>
<td>16.36</td>
<td>25.69</td>
<td>0</td>
<td>100</td>
<td>1.82</td>
<td>5.73</td>
</tr>
<tr>
<td>Department</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obstetrics and gynecology</td>
<td>683</td>
<td>3.07</td>
<td>10.36</td>
<td>0</td>
<td>100</td>
<td>4.73</td>
<td>31.81</td>
</tr>
<tr>
<td>Eye</td>
<td>175</td>
<td>31.43</td>
<td>40.86</td>
<td>0</td>
<td>100</td>
<td>0.83</td>
<td>1.93</td>
</tr>
<tr>
<td>Ear Nose Throat</td>
<td>243</td>
<td>8.23</td>
<td>22.02</td>
<td>0</td>
<td>100</td>
<td>2.95</td>
<td>11.01</td>
</tr>
<tr>
<td>Pediatrics</td>
<td>3,418</td>
<td>17.44</td>
<td>26.98</td>
<td>0</td>
<td>100</td>
<td>1.70</td>
<td>5.15</td>
</tr>
<tr>
<td>Medicine</td>
<td>11,071</td>
<td>7.37</td>
<td>17.22</td>
<td>0</td>
<td>100</td>
<td>3.06</td>
<td>13.48</td>
</tr>
<tr>
<td>Surgery</td>
<td>18,840</td>
<td>10.45</td>
<td>21.04</td>
<td>0</td>
<td>100</td>
<td>2.58</td>
<td>9.85</td>
</tr>
<tr>
<td>Indication for performing hand hygiene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before touching a patient</td>
<td>7,904</td>
<td>7.53</td>
<td>17.03</td>
<td>0</td>
<td>100</td>
<td>3.01</td>
<td>13.30</td>
</tr>
<tr>
<td>After touching a patient</td>
<td>7,781</td>
<td>7.67</td>
<td>17.32</td>
<td>0</td>
<td>100</td>
<td>2.99</td>
<td>13.07</td>
</tr>
<tr>
<td>Before clean/aseptic procedures</td>
<td>4,266</td>
<td>18.93</td>
<td>28.68</td>
<td>0</td>
<td>100</td>
<td>1.63</td>
<td>4.74</td>
</tr>
<tr>
<td>After body fluid exposure/risk</td>
<td>4,780</td>
<td>17.67</td>
<td>28.16</td>
<td>0</td>
<td>100</td>
<td>1.72</td>
<td>5.05</td>
</tr>
<tr>
<td>After touching patient surroundings</td>
<td>9,699</td>
<td>6.52</td>
<td>15.14</td>
<td>0</td>
<td>100</td>
<td>3.12</td>
<td>14.82</td>
</tr>
</tbody>
</table>
D.10: Characteristic of hand hygiene compliance by the variables and during after intervention

<table>
<thead>
<tr>
<th>Variables</th>
<th>After intervention (n = 22,646)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Overall</td>
<td>22,646</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>3,874</td>
</tr>
<tr>
<td>Female</td>
<td>18,772</td>
</tr>
<tr>
<td>Type of HCW</td>
<td></td>
</tr>
<tr>
<td>Doctor</td>
<td>609</td>
</tr>
<tr>
<td>Registered Nurse</td>
<td>12,667</td>
</tr>
<tr>
<td>Technical Nurse</td>
<td>506</td>
</tr>
<tr>
<td>Nursing Assistant</td>
<td>1,233</td>
</tr>
<tr>
<td>Nursing Aide</td>
<td>4,306</td>
</tr>
<tr>
<td>Worker</td>
<td>1,816</td>
</tr>
<tr>
<td>Medical Student</td>
<td>101</td>
</tr>
<tr>
<td>Nursing Student</td>
<td>1,084</td>
</tr>
<tr>
<td>Visitor</td>
<td>324</td>
</tr>
</tbody>
</table>
### D.10: Characteristic of hand hygiene compliance by the variables and during after intervention (cont.)

<table>
<thead>
<tr>
<th>Variables</th>
<th>After intervention (n = 22,646)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td><strong>Ward type</strong></td>
<td></td>
</tr>
<tr>
<td>Non-ICU wards</td>
<td>16,089</td>
</tr>
<tr>
<td>ICU wards</td>
<td>6,557</td>
</tr>
<tr>
<td><strong>Department</strong></td>
<td></td>
</tr>
<tr>
<td>Obstetrics and gynecology</td>
<td>2,760</td>
</tr>
<tr>
<td>Eye</td>
<td>786</td>
</tr>
<tr>
<td>Ear Nose Throat</td>
<td>585</td>
</tr>
<tr>
<td>Pediatrics</td>
<td>4,804</td>
</tr>
<tr>
<td>Medicine</td>
<td>7,449</td>
</tr>
<tr>
<td>Surgery</td>
<td>6,262</td>
</tr>
<tr>
<td><strong>Indication for performing hand hygiene</strong></td>
<td></td>
</tr>
<tr>
<td>Before touching a patient</td>
<td>4,802</td>
</tr>
<tr>
<td>After touching a patient</td>
<td>4,697</td>
</tr>
<tr>
<td>Before clean/aseptic procedures</td>
<td>2,604</td>
</tr>
<tr>
<td>After body fluid exposure/risk</td>
<td>2,668</td>
</tr>
<tr>
<td>After touching patient surroundings</td>
<td>7,875</td>
</tr>
</tbody>
</table>
D.11: Characteristic of hand hygiene compliance by the variables during overall intervention

<table>
<thead>
<tr>
<th>Variables</th>
<th>Overall intervention ( n = 57,076)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Overall</td>
<td>57,076</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>11,711</td>
</tr>
<tr>
<td>Female</td>
<td>45,365</td>
</tr>
<tr>
<td>Type of HCW</td>
<td></td>
</tr>
<tr>
<td>Doctor</td>
<td>2,438</td>
</tr>
<tr>
<td>Registered Nurse</td>
<td>31,369</td>
</tr>
<tr>
<td>Technical Nurse</td>
<td>1,094</td>
</tr>
<tr>
<td>Nursing Assistant</td>
<td>2,892</td>
</tr>
<tr>
<td>Nursing Aide</td>
<td>10,863</td>
</tr>
<tr>
<td>Worker</td>
<td>3,911</td>
</tr>
<tr>
<td>Medical Student</td>
<td>519</td>
</tr>
<tr>
<td>Nursing Student</td>
<td>2,445</td>
</tr>
<tr>
<td>Visitor</td>
<td>1,545</td>
</tr>
<tr>
<td>Ward type</td>
<td></td>
</tr>
<tr>
<td>Non-ICU wards</td>
<td>38,425</td>
</tr>
<tr>
<td>ICU wards</td>
<td>18,651</td>
</tr>
</tbody>
</table>
D.11: Characteristic of hand hygiene compliance by the variables during overall intervention (cont.)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Overall intervention (n = 57,076)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Department</td>
<td></td>
</tr>
<tr>
<td>Obstetrics and gynecology</td>
<td>3,443</td>
</tr>
<tr>
<td>Eye</td>
<td>961</td>
</tr>
<tr>
<td>Ear Nose Throat</td>
<td>828</td>
</tr>
<tr>
<td>Pediatrics</td>
<td>8,222</td>
</tr>
<tr>
<td>Medicine</td>
<td>18,520</td>
</tr>
<tr>
<td>Surgery</td>
<td>25,102</td>
</tr>
<tr>
<td>Indication for performing hand hygiene</td>
<td></td>
</tr>
<tr>
<td>Before touching a patient</td>
<td>12,706</td>
</tr>
<tr>
<td>After touching a patient</td>
<td>12,478</td>
</tr>
<tr>
<td>Before clean/aseptic procedures</td>
<td>6,870</td>
</tr>
<tr>
<td>After body fluid exposure/risk</td>
<td>7,448</td>
</tr>
<tr>
<td>After touching patient surroundings</td>
<td>17,574</td>
</tr>
</tbody>
</table>
D.12: Compliance with hand hygiene at before and at after intervention

<table>
<thead>
<tr>
<th></th>
<th>Before intervention</th>
<th></th>
<th>After intervention</th>
<th></th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of HH events</td>
<td>No. of HH opportunities</td>
<td>Compliance (%)</td>
<td>No. of HH events</td>
<td>No. of HH opportunities</td>
</tr>
<tr>
<td>Overall</td>
<td>8,013</td>
<td>34,430</td>
<td>10.10</td>
<td>4,943</td>
<td>22,646</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1,917</td>
<td>7,837</td>
<td>5.33</td>
<td>886</td>
<td>3,874</td>
</tr>
<tr>
<td>Female</td>
<td>6,096</td>
<td>26,593</td>
<td>11.50</td>
<td>4,057</td>
<td>18,772</td>
</tr>
<tr>
<td>Type of HCW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctor</td>
<td>497</td>
<td>1,829</td>
<td>5.41</td>
<td>140</td>
<td>609</td>
</tr>
<tr>
<td>Registered Nurse</td>
<td>4,244</td>
<td>18,702</td>
<td>14.56</td>
<td>2,702</td>
<td>12,667</td>
</tr>
<tr>
<td>Technical Nurse</td>
<td>147</td>
<td>588</td>
<td>12.41</td>
<td>139</td>
<td>506</td>
</tr>
<tr>
<td>Nursing Assistant</td>
<td>335</td>
<td>1,659</td>
<td>5.97</td>
<td>230</td>
<td>1,233</td>
</tr>
<tr>
<td>Nursing Aide</td>
<td>1,387</td>
<td>6,557</td>
<td>4.12</td>
<td>904</td>
<td>4,306</td>
</tr>
<tr>
<td>Worker</td>
<td>523</td>
<td>2,095</td>
<td>3.96</td>
<td>461</td>
<td>1,816</td>
</tr>
<tr>
<td>Medical Student</td>
<td>118</td>
<td>418</td>
<td>2.87</td>
<td>29</td>
<td>101</td>
</tr>
<tr>
<td>Nursing Student</td>
<td>393</td>
<td>1,361</td>
<td>5.44</td>
<td>251</td>
<td>1,084</td>
</tr>
<tr>
<td>Visitor</td>
<td>370</td>
<td>1,221</td>
<td>3.52</td>
<td>87</td>
<td>324</td>
</tr>
</tbody>
</table>
### D.12:  Compliance with hand hygiene at before and at after intervention (cont.)

<table>
<thead>
<tr>
<th>Ward type</th>
<th>Before intervention</th>
<th>After intervention</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of HH events</td>
<td>No. of HH opportunities</td>
<td>Compliance (%)</td>
</tr>
<tr>
<td>Non-ICU wards</td>
<td>5,032</td>
<td>22,336</td>
<td>6.70</td>
</tr>
<tr>
<td>ICU wards</td>
<td>2,981</td>
<td>12,094</td>
<td>16.36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Department</th>
<th>Before intervention</th>
<th>After intervention</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obstetrics and gynecology</td>
<td>176</td>
<td>683</td>
<td>3.07</td>
</tr>
<tr>
<td>Eye</td>
<td>35</td>
<td>175</td>
<td>31.43</td>
</tr>
<tr>
<td>Ear Nose Throat</td>
<td>65</td>
<td>243</td>
<td>8.23</td>
</tr>
<tr>
<td>Pediatrics</td>
<td>873</td>
<td>3,418</td>
<td>17.44</td>
</tr>
<tr>
<td>Medicine</td>
<td>2,478</td>
<td>11,071</td>
<td>7.37</td>
</tr>
<tr>
<td>Surgery</td>
<td>4,386</td>
<td>18,840</td>
<td>10.45</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indication for performing hand hygiene</th>
<th>Before touching a patient</th>
<th>After touching a patient</th>
<th>Before clean/aseptic procedures</th>
<th>After body fluid exposure/risk</th>
<th>After touching patient surroundings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7,904</td>
<td>7,781</td>
<td>4,266</td>
<td>4,780</td>
<td>9,699</td>
</tr>
<tr>
<td></td>
<td>7.53</td>
<td>7.67</td>
<td>18.93</td>
<td>17.67</td>
<td>6.52</td>
</tr>
<tr>
<td></td>
<td>4,802</td>
<td>4,697</td>
<td>2,604</td>
<td>2,668</td>
<td>7,875</td>
</tr>
<tr>
<td></td>
<td>9.31</td>
<td>9.28</td>
<td>17.20</td>
<td>16.86</td>
<td>7.09</td>
</tr>
</tbody>
</table>
Appendix E

Publications arising directly from the thesis
Increasing Incidence of Hospital-Acquired and Healthcare-Associated Bacteremia in Northeast Thailand: A Multicenter Surveillance Study

Maliwan Hongsuwan1, Pramot Srisamang2, Manas Kanoksil3, Nantasit Luangasanatip1, Anchalee Jatapai1, Nicholas P. Day1,4, Sharon J. Peacock1,5,6, Ben S. Cooper1,4, Direk Limmathurotsakul1,7*

1 Mahidol-Oxford Tropical Medicine Research Unit, Faculty of Tropical Medicine, Mahidol University, Bangkok, Thailand, 2 Department of pediatrics, Sappasithiprasong Hospital, Ubon Ratchathani, Thailand, 3 Department of pediatrics, Udon Thani Hospital, Udon Thani, Thailand, 4 Center for Tropical Medicine, Nuffield Department of Clinical Medicine, University of Oxford, Oxford, United Kingdom, 5 Department of Microbiology and Immunology, Faculty of Tropical Medicine, Mahidol University, Bangkok, Thailand, 6 Department of Medicine, Cambridge University, Addenbrooke’s Hospital, Cambridge, United Kingdom, 7 Department of Tropical Medicine, Mahidol University, Bangkok, Thailand

Abstract

Background: Little is known about the epidemiology of nosocomial bloodstream infections in public hospitals in developing countries. We evaluated trends in incidence of hospital-acquired bacteremia (HAB) and healthcare-associated bacteremia (HCAB) and associated mortality in a developing country using routinely available databases.

Methods: Information from the microbiology and hospital databases of 10 provincial hospitals in northeast Thailand was linked with the national death registry for 2004–2010. Bacteremia was considered hospital-acquired if detected after the first two days of hospital admission, and healthcare-associated if detected within two days of hospital admission with a prior inpatient episode in the preceding 30 days.

Results: A total of 3,424 patients out of 1,069,443 at risk developed HAB and 2,184 out of 119,286 at risk had HCAB. Of these, 1,559 (45.5%) and 913 (41.8%) died within 30 days, respectively. Between 2004 and 2010, the incidence rate of HAB increased from 0.6 to 0.8 per 1,000 patient-days at risk (p < 0.001), and the cumulative incidence of HCAB increased from 1.2 to 2.0 per 100 readmissions (p < 0.001). The most common causes of HAB were Acinetobacter spp. (16.2%), Klebsiella pneumoniae (13.9%), and Staphylococcus aureus (13.9%), while those of HCAB were Escherichia coli (26.3%), S. aureus (14.0%), and K. pneumoniae (9.7%). There was an overall increase over time in the proportions of ESBL-producing E. coli causing HAB and HCAB.

Conclusions: This study demonstrates a high and increasing incidence of HAB and HCAB in provincial hospitals in northeast Thailand, increasing proportions of ESBL-producing isolates, and very high associated mortality.

Introduction

Nosocomial infections are the most frequent adverse event in healthcare delivery worldwide, but there is a paucity of information about their epidemiology from developing countries [1]. This is particularly true for nosocomial bacteremia which are frequently used as indicators of trends in overall nosocomial infection in developed countries because of the availability of clear definitions and clinical relevance [2,3]. A recent comprehensive systematic review found only 13 studies of bloodstream infection from developing countries between 1995 and 2008, with only six studies in the Southeast Asia region and none from the Western Pacific region [1]. For example, the reported incidence rates of hospital-acquired bacteremia (HAB) through active surveillance were 1.0 per 1,000 patient-days in a district hospital in Kenya between 2002–2009 [4], and 1.2 per 1,000 patient-days in a
Study population
Northeast Thailand consists of 20 provinces, covers 170,226 km² and had an estimated population in 2010 of 21.4 million. Each province has a provincial hospital that provides care to people living within its catchment area and acts as a referral hospital for smaller district hospitals. The number of beds per provincial hospital ranges from 200 to 1000, and all provincial hospitals are equipped with intensive care units (ICUs). Severely ill patients presenting to district hospitals are often referred to provincial hospitals. Provincial hospitals are equipped with a microbiology laboratory that provides a bacterial culture service, while district hospitals normally do not have such facilities. All microbiology laboratories in provincial hospitals use standard methodologies for bacterial identification and susceptibility testing provided by the Bureau of Laboratory Quality and Standards, Ministry of Public Health, Thailand [7].

Study design
We conducted a retrospective, multicenter surveillance study of all provincial hospitals in northeast Thailand. The data were collected as previously described [2]. In brief, the director of each hospital was contacted and given information on the study. For those hospitals that agreed to participate, data were collected from the microbiology and hospital databases between Jan 2004 to Dec 2010. Admission number (AN) was used as the record linkage between the two databases, and hospital number (HN) was used to identify individuals who had repeated admissions. The death registry for northeast Thailand between Jan 2004 to Jan 2011 was obtained from the Ministry of Interior, Thailand, and used to identify patients who were discharged from hospital and died within 30 days after discharge from the hospital. Ethical permission for this study was obtained from the Ethical and Scientific Review Committees of Faculty of Tropical Medicine, Mahidol University, and of the Ministry of Public Health, Thailand. Written consent was given by the director of the hospitals to use the routine hospital database for research. Consent was not sought from the patients as this was a retrospective study, and the Ethical and Scientific Review Committees approved the process.

Data collection
The microbiology laboratory data collected were HN, AN, specimen type, specimen date, culture result, and antibiotic susceptibility profile (antibiogram). Hospital data were collected from the routine in-patient discharge report (Report 501), which is regularly completed by attending physicians and reported to the Ministry of Public Health, Thailand, as part of national morbidity and mortality reporting system. The data collected were HN, AN, national identification 13-digit number, gender, age, admission date, discharge date, and outcome. A single outcome variable is required by this reporting system, which is completed by the attending physicians and categorized as cured, improved, not improved, transfer to another hospital, refusal of treatment, or died. Date of death was also extracted from this record. Data collected from the death registry obtained from the Ministry of Interior were national identification 13-digit number and date of death. Data are not suitable for public deposition due to ethical restrictions. Raw database requests may be made to the director of each participating hospital (Table S1).

Definitions
Bacteremia was classified as community-acquired bacteremia (CAB). HAB or HCAB was defined as the isolation of a pathogenic organism from blood taken in the first 2 days of admission and without a hospital stay in the 30 days prior to admission [2]. HAB was defined as the isolation of a pathogenic organism from blood taken after the first 2 days of admission [8,9]. HCAB was defined as the isolation of a pathogenic organism from blood taken in the first 2 days of admission and with a hospital stay within 30 days prior to the admission [8,9]. Patients at risk of HCAB were those with a hospital stay within 30 days prior to the admission. Patients were considered at risk of HAB after they stayed in the hospital for more than 2 days. Because of the difficulty in establishing their clinical significance, organisms frequently associated with contamination including coagulase-negative Staphylococci, viridans group streptococci, Corynebacterium spp., Bacillus spp., Diptheroid spp., Micrococcus spp., and Propionibacterium spp. were excluded from the analysis [10]. Organisms that produced an extended-spectrum β lactamase (ESBL) were defined using standard methodologies for bacterial identification and susceptibility testing provided by the Bureau of Laboratory Quality and Standards, Ministry of Public Health, Thailand [7]. All patients with bacteremia caused by B. pseudodallei were categorized as CAB because this organism is not a cause of HAB or HCAB [11]. Polymicrobial infection was defined in patients who had more than one species of pathogenic organisms isolated from the blood during the same episode. Information on patients with a first CAB episode has been published previously [2]. In this study, patients with a first episode of HAB or HCAB were evaluated in relation to epidemiology and mortality.

The 30-day mortality of HAB was determined on the basis of a record of death within 30 days of the positive blood culture taken as recorded in the routine hospital database or by a record of death in the national death registry. The 30-day mortality of HCAB was defined as death within 30 days of the admission date. The incidence rate of HAB was calculated as the number of HAB per 1,000 patient-days at risk. The cumulative incidence of HCAB was calculated as the number of HCAB per 100 readmissions. To avoid the assessment of multiple outcomes for a single patient, in the event that a patient had more than one episode of bacteremia (either HAB and/or HCAB) only the first episode was included in the study.

Statistical analysis
All analyses were performed using STATA version 12.0 (StataCorp LP, College station, Texas). Poisson regression models were used to calculated incidence rate ratios, and logistic regression models were used to calculated odds ratios. Fisher’s exact test was used to compare categorical variables. The Mann-Whitney test was used to compare continuous variables. A non-parametric test for trend was used to assess change in proportion...
over time and stratified by hospital (using the npt_s command in STATA).

**Results**

All 20 provincial hospitals in northeast Thailand were contacted to participate in this study. Agreement was obtained from 15 (75%) hospitals, of which 10 had microbiological laboratory and hospital databases as electronic files in a readily accessible format (Figure S1). Of the 10 hospitals included in the analysis, 3 (30%) had data available for the period 2004–2010, 1 (10%) between 2006–2010, 2 (20%) between 2007–2010, 3 (30%) between 2008–2010, and 1 (10%) between 2009–2010 (Tables 1 and 2). The median bed number was 450 beds (range 300 to 1,000 beds). A total of 1,969,474 admission records from 1,372,446 patients were evaluated, of which 21,438 (1.1%) admission records had at least one blood culture positive for pathogenic organisms during admission. A total of 3,451 (16.1%) episodes were defined as hospital-acquired bacteremia (HAB); 2,302 (10.7%) episodes were healthcare-associated bacteremia (HCAB) and 15,685 (73.2%) episodes were community-acquired bacteremia (CAB). Multiple episodes of HAB and HCAB were noted in 26 and 102 patients, respectively. Only the first episodes of HAB and HCAB in 3,424 and 2,184 patients, respectively, were included in further analysis.

**Incidence of HAB and HCAB**

The average incidence rate for HAB during the 7-year study period was 0.7 per 1,000 patient-days, with an overall increase in rate over time. The incidence rate of HAB increased from 0.6 in 2004 to 0.8 per 1,000 patient-days in 2010 (p<0.001) (Table 1).

Of 1,969,474 admission records, 119,286 (10.1%) had a hospital stay within 30 days prior to admission and were at risk of HCAB. The cumulative incidence for HCAB during the 7-year study period was 1.8 per 100 readmissions, with an overall increase in the cumulative incidence over time. The cumulative incidence of HCAB increased from 1.2 in 2004 to 2.0 per 100 readmissions in 2010 (p<0.001) (Table 2). The incidence rate of HAB and HCAB varied by hospitals (Figure S2 and S3), but the overall increasing trends were observed in most hospitals.

**Demographic risk factors for HAB and HCAB**

Of 3,424 patients with a primary episode of HAB, 2,000 (58.4%) were male and 1,424 (41.6%) were female. The median age was 51 years (interquartile range [IQR] 16–67 years, range 0–88 years). The median time from hospital admission to bacteremia was 8 days (IQR 4–15 days, range 3–105 days). The median length of stay for patients with HAB was longer than patients who were at risk of, but did not develop HAB (18 vs. 4 days, p<0.001). The overall incidence rate of HAB was higher in males than in females (0.8 vs. 0.6 per 1,000 patient-days, incidence rate ratio [IRR] 1.21; 95% confidence interval [CI] 1.13 to 1.30, p<0.001) (Figure 1). The incidence rates of HAB were highest in infants (1.1 per 1,000 patient-days), and in those older than 80 years of age (0.9 per 1,000 patient-days).

Of 2,184 patients with a primary episode of HCAB, 1,166 (53.4%) were male and 1,018 (46.6%) were female. Median age was 57 years (IQR 41–70 years, range 0–89 years). The median time between prior and study admission was 11 days (IQR 6–19 days, range 1–30 days). The median length of stay for patients with HCAB was longer than patients who were at risk of, but did not present with HCAB (6 vs. 3 days, p<0.001). Male gender was associated with a higher risk of HCAB (odds ratio [OR] 1.29; 95%CI 1.18 to 1.40, p<0.001) (Figure 2). The incidence rates of

---

<table>
<thead>
<tr>
<th>Year</th>
<th>Total number of hospitals with available data</th>
<th>Total number of hospital admissions</th>
<th>Total number of patients with HAB</th>
<th>Deaths associated with HAB</th>
<th>30-day mortality associated with HAB</th>
<th>Incidence rate for HAB (per 1,000 patient-days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>3</td>
<td>123,376</td>
<td>74,272</td>
<td>212</td>
<td>90</td>
<td>42.5%</td>
</tr>
<tr>
<td>2005</td>
<td>3</td>
<td>128,816</td>
<td>79,254</td>
<td>292</td>
<td>120</td>
<td>41.1%</td>
</tr>
<tr>
<td>2006</td>
<td>4</td>
<td>189,812</td>
<td>102,948</td>
<td>259</td>
<td>100</td>
<td>38.6%</td>
</tr>
<tr>
<td>2007</td>
<td>6</td>
<td>241,208</td>
<td>123,574</td>
<td>366</td>
<td>186</td>
<td>43.0%</td>
</tr>
<tr>
<td>2008</td>
<td>9</td>
<td>372,564</td>
<td>199,154</td>
<td>505</td>
<td>281</td>
<td>43.1%</td>
</tr>
<tr>
<td>2009</td>
<td>10</td>
<td>453,791</td>
<td>239,814</td>
<td>438</td>
<td>384</td>
<td>43.6%</td>
</tr>
<tr>
<td>2010</td>
<td>10</td>
<td>445,407</td>
<td>244,427</td>
<td>395</td>
<td>395</td>
<td>44.5%</td>
</tr>
<tr>
<td>Overall</td>
<td>10</td>
<td>1,969,474</td>
<td>1,069,443</td>
<td>3,424</td>
<td>1,559</td>
<td>45.5%</td>
</tr>
</tbody>
</table>

*Patients at risk of HAB were patients who stayed in the hospital longer than 2 days.

Table 1. Incidence rates of hospital-acquired bacteremia (HAB) and associated death rate between 2004 and 2010 in northeast Thailand.

DOI:10.1371/journal.pone.0109324.t001
HCAB were high in infants (1.1 per 100 readmission), and very high in those older than 30 years of age (Figure 2).

Pathogenic organisms associated with HAB and HCAB

Of all pathogenic organisms causing HAB, 2,313 (67.6%) were Gram-negative bacteria, 885 (25.8%) were Gram-positive bacteria, 81 (2.4%) were fungi, 3 (0.1%) were Mycobacterium spp., and 141 (4.1%) were polymicrobial (Table 3). The most common pathogens identified were Acinetobacter spp. (16.2%), Klebsiella pneumoniae (13.9%), Staphylococcus aureus (13.9%), Escherichia coli (12.6%), and Pseudomonas spp. (10.5%). Of all pathogenic organisms causing HCAB, 1,470 (67.3%) were Gram-negative bacteria, 592 (27.1%) were Gram-positive bacteria, 24 (1.1%) were fungi, 4 (0.2%) were Mycobacterium spp., and 94 (4.3%) were polymicrobial (Table 3). The most common pathogens identified were Escherichia coli (26.3%), S. aureus (14.0%), Klebsiella pneumoniae (9.7%), Pseudomonas spp. (8.8%), and Acinetobacter spp. (5.7%). The proportion of ESBL-producing Enterobacteriaceae was 37.0% (176/477). Corresponding proportions of carbapenem-resistant Enterobacteriaceae were 3.8% (69/1,851) and 3.4% (23/677), respectively. HABs were predominantly of methicillin-resistant S. aureus (MRSA), 37.0% (176/477). Corresponding proportions of extended-spectrum β-lactamase (ESBL)-producing E. coli and K. pneumoniae were 38.9% (169/434) and 59.3% (283/477), respectively.

Table 2. Cumulative incidence of healthcare-associated bacteremia (HCAB) and associated death rate between 2004 and 2010 in northeast Thailand.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total number of hospitals with available data</th>
<th>Total number of hospital admissions</th>
<th>Total number of hospital admission at risk of HCAB*</th>
<th>Total number of patients with HCAB</th>
<th>Deaths associated with HCAB</th>
<th>30-day mortality associated with HCAB</th>
<th>Cumulative incidence for HCAB (per 100 readmissions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>3</td>
<td>129,376</td>
<td>7,259</td>
<td>86</td>
<td>44</td>
<td>51.2%</td>
<td>1.2</td>
</tr>
<tr>
<td>2005</td>
<td>3</td>
<td>138,816</td>
<td>8,266</td>
<td>125</td>
<td>41</td>
<td>32.8%</td>
<td>1.5</td>
</tr>
<tr>
<td>2006</td>
<td>4</td>
<td>187,812</td>
<td>10,960</td>
<td>157</td>
<td>68</td>
<td>43.3%</td>
<td>1.4</td>
</tr>
<tr>
<td>2007</td>
<td>6</td>
<td>241,209</td>
<td>14,234</td>
<td>272</td>
<td>117</td>
<td>43.0%</td>
<td>1.9</td>
</tr>
<tr>
<td>2008</td>
<td>9</td>
<td>372,564</td>
<td>22,601</td>
<td>435</td>
<td>198</td>
<td>45.5%</td>
<td>1.9</td>
</tr>
<tr>
<td>2009</td>
<td>10</td>
<td>453,790</td>
<td>26,969</td>
<td>527</td>
<td>206</td>
<td>39.1%</td>
<td>2.0</td>
</tr>
<tr>
<td>2010</td>
<td>10</td>
<td>445,907</td>
<td>28,997</td>
<td>582</td>
<td>239</td>
<td>41.1%</td>
<td>2.0</td>
</tr>
<tr>
<td>Overall</td>
<td>10</td>
<td>1,969,474</td>
<td>119,286</td>
<td>2,184</td>
<td>913</td>
<td>41.8%</td>
<td>1.8</td>
</tr>
</tbody>
</table>

*Patients at risk of HCAB were patients who had a hospital stay within 30 days prior to the admission. doi:10.1371/journal.pone.0109324.t002

Figure 1. Age- and gender-specific incidence rates of hospital-acquired bacteremia (HAB) and HCAB between 2004 and 2010 in northeast Thailand.

Figure 2. Cumulative incidence for HCAB (per 100 readmissions) and age- and gender-specific cumulative incidence rates of healthcare-associated bacteremia (HCAB) between 2004 and 2010 in northeast Thailand.

Incidence rate of HAB (per 1,000 patient-days)
producing *K. pneumoniae* and MRSA were 30.4% (175/575), 33.2% (70/211), and 24.3% (74/305), respectively. There were no differences in the patterns of common pathogens identified among different provinces or over the study period. However, there was an overall increase in the proportions of ESBL-producing *E. coli* over time. From 2004 to 2010, the proportion of ESBL-producing *E. coli* causing HAB rose from 33.3% (10/30) to 51.5% (51/99) (p = 0.005), and that causing HCAB rose from 20.8% (5/24) to 32.9% (48/146) (p < 0.001). The rising trend of ESBL-producing *E. coli* was observed in most hospitals. We did not observe a clear overall trend in the proportions of ESBL-producing *K. pneumoniae* or MRSA.

Mortality associated with HAB and HCAB

Death within 30 days of admission with an episode of HCAB was identified in 913 patients, giving an overall 30-day mortality of 41.8% (Table 2). Considering all patients who had a hospital stay within 30 days prior to admission, the mortality of those with HCAB was significantly higher than those without HCAB (41.8% [913/2,184] vs. 13.0% [15,168/117,102], p < 0.001). Death in HCAB patients also occurred rapidly, with 410 of 913 deaths (45.7%) occurring within the first two days of admission, 54 (6.0%) on day 3, and 46 (5.1%) on day 4. Death in HCAB patients occurred in hospital in 43.2% (394/913) of cases, the remainder occurring after hospital discharge. There was no change in the 30-day mortality associated with HCAB over time (p = 0.36).

**Discussion**

Our study showed that nosocomial infection is an increasing and important problem in northeast Thailand. The total number of deaths associated with HAB and HCAB in 2010 in our study (n = 634) were much higher than the total number of reported deaths due to important notifiable diseases such as dengue hemorrhagic fever (n = 139), influenza (n = 126), and leptospirosis (n = 43) during the same period countrywide [12]. There was a 32.3% increase in the incidence rate of HAB and 66.8% in the cumulative incidence of HCAB between 2004 and 2010 in northeast Thailand. These estimates reinforce the need for

**Table 3.** Pathogenic organisms associated with hospital-acquired bacteremia (HAB) or healthcare-acquired bacteremia (HCAB).

<table>
<thead>
<tr>
<th>Organisms</th>
<th>HAB</th>
<th>HCAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gram negative bacteria</td>
<td>2,313 (67.6%)</td>
<td>1,470 (67.3%)</td>
</tr>
<tr>
<td><em>Acinetobacter</em> spp.</td>
<td>554 (16.2%)</td>
<td>124 (5.7%)</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>265 (7.7%)</td>
<td>400 (18.3%)</td>
</tr>
<tr>
<td>ESBL –ve</td>
<td>169 (4.9%)</td>
<td>175 (8.0%)</td>
</tr>
<tr>
<td>ESBL +ve</td>
<td>194 (5.7%)</td>
<td>141 (6.5%)</td>
</tr>
<tr>
<td><em>Klebsiella pneumoniae</em></td>
<td>283 (8.3%)</td>
<td>70 (3.2%)</td>
</tr>
<tr>
<td><em>Enterococcus</em> spp.</td>
<td>122 (3.6%)</td>
<td>55 (2.5%)</td>
</tr>
<tr>
<td><em>Pseudomonas</em> spp.</td>
<td>155 (4.5%)</td>
<td>44 (2.0%)</td>
</tr>
<tr>
<td>Other Gram-negative bacteria</td>
<td>213 (6.2%)</td>
<td>256 (11.7%)</td>
</tr>
<tr>
<td>Gram positive bacteria</td>
<td>885 (25.8%)</td>
<td>592 (27.1%)</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>300 (8.8%)</td>
<td>231 (10.6%)</td>
</tr>
<tr>
<td>Methicillin-susceptible</td>
<td>176 (5.1%)</td>
<td>74 (3.4%)</td>
</tr>
<tr>
<td>Methicillin-resistant</td>
<td>173 (5.1%)</td>
<td>74 (3.4%)</td>
</tr>
<tr>
<td><em>Enterococcus</em> spp.</td>
<td>236 (6.9%)</td>
<td>213 (9.8%)</td>
</tr>
<tr>
<td><em>Fungi</em></td>
<td>81 (2.4%)</td>
<td>24 (1.1%)</td>
</tr>
<tr>
<td>Cryptococcus* spp.</td>
<td>16 (0.5%)</td>
<td>20 (0.9%)</td>
</tr>
<tr>
<td><em>Candida</em> spp.</td>
<td>59 (1.7%)</td>
<td>4 (0.2%)</td>
</tr>
<tr>
<td><em>Penicillium</em> spp.</td>
<td>6 (0.2%)</td>
<td>–</td>
</tr>
<tr>
<td>Histoplasma* spp.</td>
<td>1 (0.0%)</td>
<td>–</td>
</tr>
<tr>
<td><em>Mycobacterium</em> spp.</td>
<td>3 (0.1%)</td>
<td>4 (0.2%)</td>
</tr>
<tr>
<td>Polymicrobial infection</td>
<td>141 (4.1%)</td>
<td>94 (4.3%)</td>
</tr>
<tr>
<td>Overall</td>
<td>3,424 (100.0%)</td>
<td>2,184 (100.0%)</td>
</tr>
</tbody>
</table>

DOI:10.1371/journal.pone.0109324.t003

Death within 30 days of admission with an episode of HCAB was identified in 913 patients, giving an overall 30-day mortality of 41.8% (Table 2). Considering all patients who had a hospital stay within 30 days prior to the admission, the mortality of those with HCAB was significantly higher than those without HCAB (41.8% [913/2,184] vs. 13.0% [15,168/117,102], p < 0.001). Death in HCAB patients also occurred rapidly, with 410 of 913 deaths (45.7%) occurring within the first two days of admission, 54 (6.0%) on day 3, and 46 (5.1%) on day 4. Death in HCAB patients occurred in hospital in 43.2% (394/913) of cases, the reminder occurring after hospital discharge. There was no change in the 30-day mortality associated with HCAB over time (p = 0.36).

**Discussion**

Our study showed that nosocomial infection is an increasing and important problem in northeast Thailand. The total number of deaths associated with HAB and HCAB in 2010 in our study (n = 634) were much higher than the total number of reported deaths due to important notifiable diseases such as dengue hemorrhagic fever (n = 139), influenza (n = 126), and leptospirosis (n = 43) during the same period countrywide [12]. There was a 32.3% increase in the incidence rate of HAB and 66.8% in the cumulative incidence of HCAB between 2004 and 2010 in northeast Thailand. These estimates reinforce the need for
improved surveillance and prevention of nosocomial infection in developing countries.

An incidence rate of HAB in the participating hospitals in 2010 of 0.8 per 1,000 patient-days is higher than recent estimates in high-income countries, including 0.7 per 1,000 patient-days in Canada between 2007–2010 [13], 0.6 per 1,000 patient-days in the USA in 2005 [14], and 0.6 per 1,000 patient-days in Estonia between 2004–2005 [15]. The Thai data are consistent with a recent review showing that other parameters used to estimate the burden of nosocomial infection in developing countries, such as prevalence of healthcare associated infections and ICU-acquired infections, are substantially higher than in developed countries [1].

The recent surveillance study conducted by the International Nosocomial Infection Control Consortium (INICC) also found that rates of central line associated bloodstream infection (CLAB) were significantly higher in ICUs in developing countries (6.8 per 1,000 central line-days) versus those reported in US ICUs (2.0 per 1,000 central line-days) [16]. Our HAB incidence rate is, however, lower than HAB rates reported through active surveillance in some developing countries, including 1.0 per 1,000 patient-days in Kenya between 2002–2009 [4], and 1.2 per 1,000 patient-days in Iran in 2006 [5]. It is possible that active surveillance may improve the detection of HAB and nosocomial infection in our geographical region.

During the study period, Acinetobacter spp. was the most common pathogen associated with HAB, followed by K. pneumoniae and S. aureus. Acinetobacter spp. is increasingly recognized as an important cause of nosocomial infection [17], and our study confirms the importance this species as a leading cause of nosocomial infection in developing tropical countries [1,4,18]. The proportion of MRSA causing HAB in our setting (37%) was higher than that reported from developing countries [13,15,19], and is consistent with a previous review of developing countries [1]. An increase in the proportion of ESBL-producing E. coli causing HAB in our study is alarming, and is consistent with our previous report of an increase in the proportion of ESBL-producing organisms causing CAB in the same setting [6].

This study highlights an increasing incidence of HCAB in developing countries. We used the total number of patients with readmission as a denominator to estimate the cumulative incidence of HCAB rather than the total number of patients with bacteremia [8,9,20]. Our estimates showed that healthcare-associated infection was an increasing cause of readmission. The high proportion of MRSA, ESBL-producing E. coli and ESBL-producing K. pneumoniae amongst organisms causing HCAB was relatively similar to that causing HAB. Much lower resistance levels were seen in organisms causing CAB [6]. This is consistent with previous reports of HCAB in developed countries [8,9,20].

The observed increase in incidence of both HAB and HCAB could be due to a combination of an increase in the incidence of nosocomial infection associated with a rise in the number of at-risk patients (for example aging patients and those with invasive interventions), and an increase in detection of HAB and HCAB due to improved healthcare practice over time. There is evidence that the incidence rate of CLAB in developing countries can be substantially reduced using a multi-dimensional infection control approach including a bundle of interventional, education, outcome surveillance, process surveillance, feedback on CLAB rate and performance feedback [21–27].

The overall 30-day mortality with HAB of 45.5% in our setting is much higher than that typically reported in high-income countries [13,15,28], but lower than the reported in-hospital mortality of 53% from a rural district hospital in Kenya [4]. The overall 30-day mortality with HCAB of 41.8% in our setting is also much higher than typically seen in high-income countries [8,9,20]. In addition to patient-related factors, the higher mortality typically seen in developing countries may be related to the proportion of antimicrobial-resistant pathogens, empirical antibiotic regimens used, and sub-optimal severe sepsis management in resource-limited settings [4,29]. It is also possible that practice in high-income countries can detect milder bacteremia cases such as cases due to intravenous device that is then rapidly removed, while the practice in low-income countries may be less likely to achieve this.

The high mortality observed in our study also reflects post-discharge ascertainment of patient outcomes using the national death registry. We found that in 47.2% of fatal cases of HAB or HCAB death occurred after hospital discharge. This reflects a preference amongst people in the study area to die at home. Further studies need to explore how to reduce the mortality of patients with HAB and HCAB in resource-limited areas.

A limitation of this study is that more complete clinical data were not available. As data on central line days were not available, the incidence rate of CLAB per 1,000 central line days could not be estimated and benchmarked against other prospective studies [30–47]. As data on process surveillance were not available, the reasons for the increased incidence of HAB could not be systematically assessed [32,41,48,49]. Another potential limitation is that blood cultures may not have been performed for all patients with a likelihood of nosocomial infection, and this might lead to an underestimation in the incidence of HAB and HCAB among participating hospitals. In addition, data on hospitalization in other hospitals not participating in the study (for example, a district hospital or a private hospital in the province) were not available, which could have resulted in an underestimation of the incidence of HAB and HCAB in our study. It is also possible that some patients with HAB and HCAB in our study may have had contaminated cultures and were incorrectly counted. However, the high mortality in patients with HAB and HCAB suggested that true infection was more likely than culture contamination. Although our data showed that, in general, patients with HAB and HCAB stayed in the hospital longer than those without, the analysis did not take account of the high mortality associated with HAB and HCAB. The length of stay would be further extended if death of patients with HAB and HCAB could be reduced. Additional costs and extra length of stay attributable to HAB and HCAB will be further evaluated using health economic models [50,51].

Although monitoring of nosocomial infection in developing countries is hampered by incomplete routine notification, our study has shown that careful evaluation of readily available routinely collected databases can provide valuable information on the incidence and trend of HAB and HCAB. The methodology used in our study could be applied to other geographical areas where microbiological facilities are available to provide a more comprehensive global picture of the importance of nosocomial infection as a cause of death.

Supporting Information

Figure S1 Location of participating hospitals. These were situated in: (1) Loei, (2) Udon Thani, (3) Nong Khai, (4) Nakhon Phanom, (5) Chaiyaphum, (6) Mahasarakarm, (7) Yasothon, (8) Buriram, (9) Sisaket, and (10) Ubon Ratchathani. (TIF)

Figure S2 Trend in hospital-acquired bacteremia (HAB) in ten provincial hospitals in Thailand. (TIF)
Figure S3 Trend in healthcare-associated bacteremia (HCAB) in ten provincial hospitals in Thailand. (TIIF)

Table S1 List of participating hospitals. (DOCX)

Acknowledgments

We gratefully acknowledge the Bacterial Infection in North East Thailand (BINET) network for providing microbiological and hospital admission data. BINET are comprised of Chalavit Limpavithayakula, Chatchawan Viriyaphum (Nakhon Phanom hospital), Kittipan Danawiboon, Kanjana Kehatan, Wannakorn Dechnorasing (Nongkhai hospital), Narong Uentrakul (Roi Ed hospital), Somsak Chaoasirikut, Anek Jadddee, Soontorn Romaneyaceph (Sisaket hospital), Thongchai Triwiboonwanich, Somsak Kitisriworapun, Kanyapak Luangsa-ard, Kraiwuth Sriporamanont, Mongkol Fungprasertkul and Dean Sherwood for computational support.

Author Contributions

Conceived and designed the experiments: MH PS MK AJ NPD SJP DL.Performed the experiments: MH MA AJ NPD SJP DL. Analyzed the data: MH MA AJ.NPDD SJP DL. Contributed to the writing of the manuscript: MH PS MK NL AJ NPD SJP BSC DL.

References


Comparative efficacy of interventions to promote hand hygiene in hospital: systematic review and network meta-analysis

Nantasit Luangasanatip,1,2 Maliwan Hongsuwan,1 Direk Limmathurosatskul,1,3 Yoel Lubell,1,4 Andie S Lee,5,6 Stephan Harbarth,9 Nicholas P J Day,1,4 Nicholas Graves,2,7 Ben S Cooper1,4

ABSTRACT

OBJECTIVE
To evaluate the relative efficacy of the World Health Organization 2005 campaign (WHO-5) and other interventions to promote hand hygiene among healthcare workers in hospital settings and to summarize associated information on use of resources.

DESIGN
Systematic review and network meta-analysis.

DATA SOURCES
Medline, Embase, CINAHL, NHS Economic Evaluation Database, NHS Centre for Reviews and Dissemination, Cochrane Library, and the EPOC register (December 2009 to February 2014); studies selected by the same search terms in previous systematic reviews (1980-2009).

REVIEW METHODS
Included studies were randomised controlled trials, non-randomised trials, controlled before-after trials, and interrupted time series studies implementing an intervention to improve compliance with hand hygiene among healthcare workers in hospital settings and measuring compliance or appropriate proxies that met predefined quality inclusion criteria. When studies had not used appropriate analytical methods, primary data were re-analysed. Random effects and network meta-analyses were performed on studies reporting directly observed compliance with hand hygiene when they were considered sufficiently homogeneous with regard to interventions and participants. Information on resources required for interventions was extracted and graded into three levels.

RESULTS
Of 3639 studies retrieved, 41 met the inclusion criteria (six randomised controlled trials, 32 interrupted time series, one non-randomised trial, and two controlled before-after studies). Meta-analysis of two randomised controlled trials showed the addition of goal setting to WHO-5 was associated with improved compliance (pooled odds ratio 1.35, 95% confidence interval 1.04 to 1.76; P=81%). Of 22 pairwise comparisons from interrupted time series, 18 showed stepwise increases in compliance with hand hygiene, and all but four showed a trend for increasing compliance after the intervention. Network meta-analysis indicated considerable uncertainty in the relative effectiveness of interventions, but nonetheless provided evidence that WHO-5 is effective and that compliance can be further improved by adding interventions including goal setting, reward incentives, and accountability. Nineteen studies reported clinical outcomes; data from these were consistent with clinically important reductions in rates of infection resulting from improved hand hygiene for some but not all important hospital pathogens. Reported costs of interventions ranged from $225 to $4669 (£146-£3035; €204-€4229) per 1000 bed days.

CONCLUSION
Promotion of hand hygiene with WHO-5 is effective at increasing compliance in healthcare workers. Addition of goal setting, reward incentives, and accountability strategies can lead to further improvements. Reporting of resources required for such interventions remains inadequate.

Introduction
At any point in time more than 1.4 million patients around the world experience healthcare associated infections.12 Such infections cause excess morbidity and are associated with increased mortality.23 Direct contact between patients and healthcare workers who are transiently contaminated with nosocomial pathogens is believed to be the primary route of transmission for several organisms and can lead to patients becoming colonised or infected. Although hand hygiene is widely thought to be the most important activity for the prevention of nosocomial infections, a review of hand hygiene studies by the World Health Organization (WHO) found that baseline compliance with hand hygiene among healthcare workers was on average only 38.7% (range 5-89%).5

In 2005, the WHO World Alliance for Patient Safety launched a campaign, the First Global Patient Safety Challenge—“Clean Care is Safer Care”—aiming to improve hand hygiene in healthcare.4 This campaign
(WHO-5) promotes a multimodal strategy consisting of five components: system change, training and education, observation and feedback, reminders in the hospital, and a hospital safety climate. More recently, additional strategies for improving hand hygiene have been evaluated, including those based on behavioural theory.

We assessed the relative effectiveness of WHO-5 and other strategies for improving compliance with hand hygiene in healthcare workers in hospital settings. Evaluation of the evidence for the effectiveness of different interventions is complicated by three factors: firstly, most evaluations of interventions to promote hand hygiene use non-randomised study designs, and in many cases the reported analysis is inappropriate or methodological quality is too low to allow meaningful conclusions to be drawn; secondly, there is wide variation between studies in the activities to promote hand hygiene used in the comparison group; thirdly, direct head-to-head comparisons of most interventions are lacking.

We aimed to overcome these problems by restricting attention to randomised trials and high quality non-randomised studies, re-analysing data when necessary; explicitly accounting for activities to promote hand hygiene in the comparison group in each study; and using network meta-analysis to allow indirect comparison between interventions.

We also summarise information on changes in clinical and microbiological outcomes associated with interventions when this was reported. Information on resources used in different interventions is essential for those wanting to implement such interventions or evaluate their cost-effectiveness. An additional aim was therefore to document information on resources used in interventions to promote hand hygiene.

Methods

We developed a protocol and used systematic methods to identify relevant studies, screen study eligibility, and assess study quality. This protocol was not registered. This review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Search strategy

We used a two-stage search strategy. Firstly, we obtained all studies considered in two previous reviews (covering the period up to November 2009), including those that had been reported as failing to meet inclusion criteria. Secondly, we extended the search from these studies from December 2009 to February 2014. We searched Medline, Embase, Cumulative Index to Nursing and Allied Health (CINAHL), Database of Abstracts of Reviews of Effects (DARE), National Health Service Economic Evaluation Database (NHS-EED), National Health Service Centre for Reviews and Dissemination (NHS-CRD) and British Nursing Index (BNI), Cochrane Library (Cochrane database of systematic reviews, Cochrane central register of controlled trials, Cochrane methodology register, Health Technology assessment database), Clinical Trial.gov, Current Clinical Control trial, Cochrane Effective Practice and Organisation of Care Group (EPOC) register, American College of Physicians journal, and reviews of evidence based medicine. Results were limited to peer reviewed publications. To validate previous search results we also repeated the electronic search for three earlier years (1980, 1995, and 2009). The complete search strategy is provided in appendix 1.

Inclusion and exclusion

Studies were included if they met all the following initial criteria: they evaluated one or more interventions intended to improve hand hygiene compliance among healthcare workers in a hospital setting; they measured compliance with hand hygiene using opportunities with prespecified indications or using proxies linked to compliance (such as consumption of soap and alcohol hand rub); they were either randomised controlled trials, non-randomised trials, controlled before-after studies, or used an interrupted time series design.

We placed no restrictions on promotion of hand hygiene in the comparison group. Studies were excluded if they were not reported in peer reviewed publications or not written in English.

We applied a methodological filter by excluding studies that failed meet minimal quality criteria specified by the Cochrane Effectiveness Practice and Organisation of Care Group (EPOC). Acceptable study designs were randomised controlled trials and non-randomised trials (with at least two intervention and two control sites); controlled before-after studies (with outcome measures before and after the intervention from at least two intervention and two comparable control sites); and interrupted time series (with a clearly defined point in time for the intervention and outcome measures from at least three time points in both baseline and intervention periods).

Patient involvement

No patients were involved in setting the research question or the outcome measures, nor were they involved in the design and implementation of the study. There are no plans to involve patients in dissemination.

Data extraction and assessment of quality

Two reviewers (NL and BSC) independently screened the titles and abstracts of the citations obtained from the search to assess the eligibility. Consensus was reached by discussion if initial assessments differed. NL evaluated the full text and abstracted data, which was checked by BSC.

The reviewers abstracted data including study design and duration, population, activities to promote hand hygiene in both intervention and comparison groups, hand hygiene outcomes, clinical and microbiological outcomes, measurement methods, and settings. When possible, we classified hand hygiene promotion activities according to WHO guidelines on hand hygiene in healthcare. We grouped activities into eight components: system change, education, feedback, reminders,
safety climate, incentives, goal setting, and accountability (table 1). Results and raw compliance data from each study were extracted for further re-analyses. In addition, we extracted the costs of hand hygiene interventions or data on use of resources (materials and time spent on interventions) when appropriate. Additional information was obtained from the authors if it was not clear from the manuscript. For all included studies we used prespecified definitions to record the level of information (high, moderate, or low) about resources used for promotion of hand hygiene (see appendix 2).

**Assessment of risk of bias in included studies**

We used the Cochrane Collaboration's tool to assess risk of bias. Twenty-nine standard criteria for randomised controlled trials, non-randomised trials, and controlled before-after studies and seven standard criteria for interrupted time series were applied and used to classify each study’s risk of bias as low, high, or unclear.

**Data synthesis and statistical analysis**

Data synthesis was performed separately for different study designs. The primary evidence synthesis was based on studies that used direct observation to measure compliance with hand hygiene. We restricted our analysis to this outcome because it reflects the opportunities for hand hygiene.

For randomised controlled trials, we used Cochrane Review Manager (RevMan; version 5.1) to calculate the natural logarithm of the odds ratio and associated variance to estimate the pooled odds ratio with a random effects model. The same method was applied to non-randomised trials, and controlled before-after studies if applicable. Heterogeneity between studies was assessed with the I² statistic. Risk of publication bias was evaluated with an enhanced contour funnel plot.

For interrupted time series, if re-analysis was required, we used a generalised linear segmented regression analysis to estimate the stepwise change in level and change in trend associated with the intervention. This approach is similar to that proposed by Ramsey and colleagues and Vidanapathirana and colleagues, except that it accounts for the binomial nature of the data, appropriately weighting each data point by the number of observations. We accounted for any evidence of autocorrelation by using Newey-West standard errors. Analysis was performed with Stata 13 (Statacorp LP, College Station, TX). We then estimated two summary measures that combined both stepwise and trend changes. Firstly, we calculated the mean natural logarithm of the odds ratio for hand hygiene associated with the intervention, a measure of relative improvement. Secondly, we calculated the mean percentage change in compliance in the period after the intervention (compared with that expected if there had been no intervention), an absolute measure of improvement in compliance. Standard errors were derived with the delta method by using the emdbook package in R. Appendix 3 provides full details.

**Network meta-analysis**

Network meta-analysis aims to combine all of the evidence, both direct and indirect, to estimate the comparative efficacy of all the interventions. Each intervention strategy is represented by a node in the network. If a study directly compares two interventions they are directly connected by a link on the network and a direct comparison is possible. If two interventions are connected indirectly (for example, if there are studies comparing each with a third intervention), then indirect comparison is possible.

We used network meta-analysis to compare the relative effectiveness of four different strategies: no promotion of hand hygiene, single component interventions, WHO-5, and WHO-5 and others (table 2). We included in the network meta-analysis those studies that included only these strategies and permitted a segmented regression analysis and directly observed compliance with hand hygiene.

The effect sizes obtained from each comparison were combined in a network meta-analysis with a random effects model. Effect sizes were taken as the mean of the natural logarithm of the odds ratio for the hand hygiene intervention as estimated with the segmented regression model. Intervention rankings and associated credible intervals were obtained. Model fitting for the meta-analysis was carried out within a Bayesian

---

**Table 1 | Description of eight components of interventions to promote hand hygiene in healthcare workers**

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>System change*</td>
<td>Ensuring necessary infrastructure is available including access to water, soap and towels and alcohol based handrub at point of care</td>
</tr>
<tr>
<td>Education and training</td>
<td>Providing training or educational programme on importance of hand hygiene and correct procedures for hand hygiene for healthcare workers</td>
</tr>
<tr>
<td>Feedback</td>
<td>Monitoring hand hygiene practices among healthcare workers while providing compliance feedback to staff</td>
</tr>
<tr>
<td>Reminders at workplace</td>
<td>Prompting healthcare workers either through printed material, verbal reminders, electronic communications or other methods, to remind them about importance of hand hygiene and appropriate indications and procedures</td>
</tr>
<tr>
<td>Institutional safety climate</td>
<td>Active participation at institutional level, creating environment allowing prioritisation of hand hygiene</td>
</tr>
<tr>
<td>Goal setting</td>
<td>Setting of specific goals aimed at improving compliance with hand hygiene, which can both apply at individual and group level and can include healthcare associated infection rates</td>
</tr>
<tr>
<td>Reward incentives</td>
<td>Interventions providing any reward incentive for participants completing a particular task or reaching a certain level of compliance. Both non-financial and financial rewards are included</td>
</tr>
<tr>
<td>Accountability</td>
<td>Interventions involved with improving healthcare workers’ accountability both at individual and unit level</td>
</tr>
</tbody>
</table>

*If the intervention period included changing the location or formulation of alcohol based handrub or installing more handrub dispensers, the baseline intervention was counted as no intervention or standard practice (no system change component), even if alcohol based handrub had been used during the baseline period.

---

the bmj | 8JM 2015;351:h3728 | doi: 10.1136/bmj.h3728
hand hygiene in healthcare workers

**Table 2 | Mean odds ratios with 95% credible intervals for intervention strategies to promote hand hygiene. Results are from random effects network meta-analysis model**

<table>
<thead>
<tr>
<th>Strategies*</th>
<th>Description</th>
<th>Mean OR (95% credible interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None/current practice</td>
<td>No intervention or current practice</td>
<td>Reference</td>
</tr>
<tr>
<td>Single intervention</td>
<td>Single intervention (system change or education)</td>
<td>4.30 (0.43 to 46.57)</td>
</tr>
<tr>
<td>WHO-5</td>
<td>WHO-5 components</td>
<td>6.51 (1.58 to 31.91)</td>
</tr>
<tr>
<td>WHO-5* + others</td>
<td>WHO-5 plus incentives, goal setting, or accountability</td>
<td>11.83 (2.67 to 53.79)</td>
</tr>
</tbody>
</table>

*Model fit statistic: posterior mean residual deviance=$10.40$ and deviance information criterion (DIC)=$23.86$

†Contains five components: system change, education, feedback, reminders, and institutional safety climate (see table 1 for details).

We performed a sensitivity analysis by excluding studies that implemented multicomponent strategies in a stepwise manner without sufficient data to evaluate individual components. This led to the exclusion of three studies.

**Results**

**Overall description**

Figure 1 shows a summary of the review process. Of 3639 studies screened, 142 studies met initial inclusion criteria and 41 of these met EPOC criteria. Among these 41 studies, six were randomised controlled trials (including three cluster randomised controlled trials), 31-36 32 were interrupted time series, 28-30 37-65 one was a non-randomised trial, 66 and two were controlled before-after studies. 67 68 Appendix 5 give details of the reasons for exclusion. Applying our search strategy to three years covered by previous reviews did not yield any studies meeting our inclusion criteria that had not already been included.

Seventeen studies applied interventions to the whole hospital, while 21 studies enrolled hospital wards. Three studies allocated interventions to specific healthcare workers. 33 33 36 Twenty five studies were conducted in either a hospital-wide setting or combined intensive care units and general wards, while 11 were conducted in intensive care units or general wards alone. Of 10 studies conducted in more than one hospital, three included two or more countries. 42 48 50 Only five of the 41 studies were conducted in low or middle income countries. 33 36 46 50 51

Study periods ranged from two months to six years. In 11 studies the period was up to one year; in 17 studies it was more than a year and up to three years; and in 13 it was more than three years. Among the 32 interrupted time series, only 11 were longer than 12 months.

In 34 studies hand hygiene was observed in all types of healthcare workers with patient contact, while six studies considered only nurses and/or nursing assistants. 33 34 36 60 64 68 One study recruited only nursing students as participants. 54 One study also included patients’ relatives. 39

Six studies used a single faceted intervention: four implemented education alone 28-30 36 and two applied system change or reminders. 39 44 Seventeen studies used interventions equivalent to WHO-5, and six of these added supplemental interventions including goal setting, incentives, and accountability. 28 34 40 45 56 66 Nineteen studies implemented interventions with two to four components; four of these applied components not in WHO-5, including goal setting and incentives. 27 38 41 59

Thirty studies (four randomised controlled trials, 25 interrupted time series, and one non-randomised trial) used direct observation to measure compliance with hand hygiene. Two of these used a combination of video recorders and external observers. 37 38 Proxy measures were assessed in 19 studies including the rate of hand hygiene events, consumption of hand hygiene products (alcohol hand rub or soap), and a hand hygiene score checklist (two randomised controlled trials, 15 interrupted time series, and two controlled before and after studies). Clinical outcomes were reported in 19 studies. 28-30 35 46 47 57 59 62 63 67 69 Appendix 6 provides full study characteristics including study design, setting, intervention, and comparison groups.

Examination of funnel plots (appendix 7) did not provide any clear evidence of publication bias, though evidence for or against such bias was limited by the fact that there were no more than four studies for any pairwise comparison of strategies.

**Quality assessment**

Ten studies were considered to have a high risk of bias. Thirty one had either low or unclear risk. High risk of bias was present in all three non-randomised trials or controlled before-after studies but only in seven out of...
32 interrupted time series. No randomised controlled trials or cluster randomised controlled trials were thought to have a high risk of bias (fig 2).

The two controlled before-after studies67,68 had high risks for inadequate allocation sequence and concealment, while one non-randomised trial66 had high risk of dissimilarity in baseline outcome between experimental and control groups.

Fourteen studies (34%) had a low risk of bias due to the knowledge of allocated intervention, as these studies either measured objective outcomes (such as alcohol consumption or output from electronic counting devices) or stated that the observers were blinded to the intervention. The rest of the studies had unclear risk as they did not report whether the observers were blinded.

Risk of selective outcome reporting was unclear in 33 studies as pre-specified protocols were reported only in three randomised controlled trials.32,34,35 Two of the interrupted time series had a high risk of selective outcome reporting as they reported on a non-periodical basis.28,29 Among the interrupted time series, six had a high risk that outcomes were affected by other interventions such as a universal chlorhexidine body washing programme,32,33 reinforcement of standard precautions,42 screening and decolonisation for multidrug-resistant micro-organisms,48 quality improvement program,46,49 and antibiotic use and healthcare associated infections control policy implemented at the same time.56

**Meta-analysis/data synthesis**

**Randomised controlled trials**

Four of six randomised controlled trials measured compliance with hand hygiene by direct observation with indications similar to WHO-5.32,35 Two of these studies compared WHO-5 with WHO-5 combined with goal setting (WHO-5*).32,34 Huis and colleagues performed a cluster randomised trial in 67 wards from three hospitals in the Netherlands.34 Compliance immediately after the intervention increased from 23% to 42% in the WHO-5 arm and from 20% to 53% in the WHO-5* arm; in both arms improvements were sustained six months later. Fuller and colleagues used a three year stepped wedge design in 16 intensive care units and 44 acute care of the elderly wards and reported an absolute increase in compliance of 13-18% and 10-13%, respectively, in implementing wards.32 Only 33 of 60 enrolled wards, however, implemented the intervention (22 out of 44 elderly wards and 11 out of 16 intensive care units), and the intention to treat analysis did not show increased compliance in the elderly wards while compliance in intensive care units increased by 7-9%.

Meta-analysis (with intention to treat results) provided evidence favouring the WHO-5* strategy. The pooled odds ratio was 1.35 (95% confidence interval 1.04 to 1.76; I²=81%) (fig 3). The large heterogeneity seemed to be caused by the low fidelity to intervention in acute care of the elderly wards. Per protocol analyses gave similar odds ratios for compliance to the study by Huis and colleagues (1.67 (95% confidence interval 1.28 to 2.22) for elderly wards and 2.09 (1.55 to 2.81) for intensive care units). Two other randomised controlled trials directly reported observed compliance with hand hygiene. An individually randomised trial of an education programme versus no intervention for nurses in China reported an absolute improvement in compliance of
32.7% (95% confidence interval 15.6% to 49.7%) for opportunities before contact with patients and 20.4% (5.6% to 35.2%) for opportunities after contact (baseline compliance before and after contact was about 25% and 37%, respectively, in both arms). In Canada, a cluster randomised trial of a bundle of education, performance feedback, and visual reminders in 30 hospital units where alcohol hand rub was available at point of care in both arms (but with no other interventions in the control arm) reported a higher adherence after the intervention in the intervention arm (mean difference 6.3%, 95% confidence interval 4.3% to 8.4%). In both arms baseline compliance was low (16%).

Fisher and colleagues randomised individuals to either a control group where hand hygiene was not actively promoted or an intervention arm that used audio reminders and individual feedback. They assessed compliance using an automated system at entry to and exit from patients’ rooms. The intervention was associated with a 6.8% (95% confidence interval 2.5% to 11.1%) improvement in compliance. Salamati and colleagues randomised nursing personnel to either a motivational interviewing intervention (a behaviour modification approach initially developed to treat patients with alcoholism) or a control group. Both arms also received an educational intervention. The outcome measure was a composite hand hygiene score, which was found to increase in the intervention arm. The scoring details, however, were unclear.

Interrupted time series

Of 32 interrupted time series, 25 measured hand hygiene compliance. Only 18 studies with direct observation, however, reported the number of observations at each time point, making them eligible for re-analysis. As some of these studies were conducted at multiple sites or had multiple intervention phases, 22 pairwise comparisons from these 18 studies were available for re-analysis (fig 4). In four studies there was evidence of positive first order autocorrelation.

The baseline compliance ranged from 7.6% to 91.3%. Twelve of 22 comparisons showed a declining trend in compliance during the period before intervention; seven of these did not report any activities to promote hand hygiene before intervention, while another four used only education or reminders. Fifteen pairwise contrasts showed a positive change in trend for compliance with hand hygiene after the intervention (table 3). All but four contrasts showed both stepwise increases in compliance with hand hygiene associated with the intervention and increases in mean compliance in the period after intervention compared with that expected in the absence of the intervention. The range was wide: the mean change in hand hygiene attributed to the intervention varied between a decrease of 14.8% and an increase of 83.3% (table 3).

Two studies had an intervention period lasting at least two years; neither showed evidence for any decline in compliance over this period. In only one study was there a net trend for decreasing compliance after the intervention (fig 4).

Non-randomised trials and controlled before-after studies

Mayer and colleagues compared WHO-5 and reward incentives (WHO-5+) with a combination of system change, education, and feedback using a staggered introduction of an intervention bundle, across four out of six patient units. The WHO-5+ intervention was associated with improved compliance, which increased from 40% to 64% in one two-unit cohort and from 34% to 49% in the other.

Benning and colleagues reported a hospital-wide trend of increased soap and alcohol consumption in both intervention (package of system change, reminders, and safety climate) and control (no intervention) groups but found no evidence of an increased effect in the intervention group. Gould and colleagues found no evidence of improvement in frequency of hand decontamination in surgical intensive care wards resulting from a series of educational lectures compared with no intervention (control).

Analysis of interrupted time series and network meta-analysis

Among the 22 pairwise comparisons from interrupted time series, 18 had clear details about interventions and similar indications for compliance with hand hygiene among qualified healthcare workers. In 16 of these the intervention period included additional intervention components alongside measures to promote hand hygiene used in the baseline period, and all outcome data favoured the intervention (fig 5). In the two comparisons where there was no improvement in hand hygiene.
Fig 4 | Re-analysis of studies involving interrupted time series where the outcome was hand hygiene compliance. Points represent observations, solid lines show expected values from fitted segmented regression models, and broken lines represent extrapolated trends before intervention. SYS = system change; EDU = education; FED = feedback; REM = reminders; SAF = institutional safety climate; INC = incentives; GOAL = goal setting; ACC = accountability; WHO-5 = combined intervention strategies including SYS, EDU, FED, REM, and SAF.
Table 3 | Results of re-analysis of studies using interrupted time series to assess compliance with hand hygiene

<table>
<thead>
<tr>
<th>Study</th>
<th>Comparison</th>
<th>Baseline (intercept)</th>
<th>Coefficient (SE) for baseline trend</th>
<th>Coefficient (SE) for change in trend</th>
<th>Coefficient (SE) for change in level</th>
<th>Mean (95% CI)</th>
<th>% change in compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lee**</td>
<td>WHO-5 v WHO-5</td>
<td>44.6</td>
<td>-0.215 (0.30)</td>
<td>-0.081 (0.10)</td>
<td>0.130 (0.10)</td>
<td>0.606 (0.26)</td>
<td>29.9 (3.5 to 56.4)</td>
</tr>
<tr>
<td>Higgins*</td>
<td>WHO-5 v WHO-5</td>
<td>53.8</td>
<td>0.154 (0.29)</td>
<td>-0.281 (0.07)</td>
<td>-0.151 (0.08)</td>
<td>-0.042 (0.25)</td>
<td>-11.5 (-13.5 to -9.5)</td>
</tr>
<tr>
<td>Talbot</td>
<td>WHO-5 v WHO-5</td>
<td>44.6</td>
<td>-0.215 (0.26)</td>
<td>0.059 (0.06)</td>
<td>0.014 (0.06)</td>
<td>0.563 (0.19)</td>
<td>13.3 (-9.2 to 35.8)</td>
</tr>
<tr>
<td>Marra**</td>
<td>WHO-5 v WHO-5</td>
<td>62.3</td>
<td>0.503 (0.33)</td>
<td>0.088 (0.13)</td>
<td>-0.094 (0.13)</td>
<td>-0.007 (0.51)</td>
<td>-9.7 (-63.6 to 44.3)</td>
</tr>
<tr>
<td>Derde**</td>
<td>REM v EDU v FED</td>
<td>52.8</td>
<td>0.112 (0.04)</td>
<td>-0.015 (0.01)</td>
<td>0.133 (0.02)</td>
<td>0.346 (0.05)</td>
<td>16.3 (13.6 to 19.1)</td>
</tr>
<tr>
<td>Al-Tawfiq28</td>
<td>WHO-5 v WHO-5 v INC</td>
<td>37.2</td>
<td>-0.428 (0.17)</td>
<td>-0.009 (0.25)</td>
<td>-0.030 (0.03)</td>
<td>2.648 (0.25)</td>
<td>48.8 (45.4 to 52.3)</td>
</tr>
<tr>
<td>Ormellino37†</td>
<td>WHO-5 v WHO-5</td>
<td>30.1</td>
<td>0.014 (0.12)</td>
<td>0.187 (0.10)</td>
<td>-0.040 (0.03)</td>
<td>0.586 (0.01)</td>
<td>4.7 (2.3 to 7.1)</td>
</tr>
<tr>
<td>Chou40†</td>
<td>WHO-5 v WHO-5 v INC v GOAL</td>
<td>54.9</td>
<td>0.198 (0.03)</td>
<td>-0.039 (0.00)</td>
<td>0.151 (0.01)</td>
<td>0.453 (0.07)</td>
<td>56.4 (13.1 to 99.8)</td>
</tr>
<tr>
<td>Helms30</td>
<td>WHO-5 v WHO-5</td>
<td>45.7</td>
<td>-0.173 (0.07)</td>
<td>0.020 (0.06)</td>
<td>0.063 (0.03)</td>
<td>0.218 (0.06)</td>
<td>11.5 (3.4 to 19.6)</td>
</tr>
<tr>
<td>Kirkland39</td>
<td>WHO-5 v WHO-5</td>
<td>51.3</td>
<td>0.052 (0.14)</td>
<td>-0.097 (0.04)</td>
<td>0.111 (0.04)</td>
<td>4.443 (1.03)</td>
<td>83.3 (77.0 to 89.6)</td>
</tr>
<tr>
<td>Al-Tawfiq38†</td>
<td>WHO-5 v WHO-5 v GOAL</td>
<td>41.3</td>
<td>-0.350 (0.09)</td>
<td>-0.014 (0.02)</td>
<td>0.081 (0.07)</td>
<td>2.328 (0.21)</td>
<td>49.9 (42.8 to 57.0)</td>
</tr>
<tr>
<td>Crews57</td>
<td>EDU v SYS v EDU v FED v REM v INC v GOAL</td>
<td>50.7</td>
<td>0.028 (0.12)</td>
<td>-0.070 (0.02)</td>
<td>0.103 (0.02)</td>
<td>3.679 (0.22)</td>
<td>38.2 (35.5 to 40.9)</td>
</tr>
<tr>
<td>Talbot (phase II)*</td>
<td>EDU v WHO-5 v INC + GOAL</td>
<td>56.7</td>
<td>0.271 (0.20)</td>
<td>-0.006 (0.02)</td>
<td>0.109 (0.02)</td>
<td>0.363 (0.41)</td>
<td>18.5 (-1.4 to 38.4)</td>
</tr>
<tr>
<td>Talbot (phase II)**</td>
<td>WHO-5 v INC</td>
<td>81.1</td>
<td>1.655 (0.45)</td>
<td>-0.020 (0.01)</td>
<td>0.060 (0.01)</td>
<td>0.464 (0.05)</td>
<td>15.0 (10.6 to 19.5)</td>
</tr>
<tr>
<td>Dubbert59</td>
<td>EDU v FED</td>
<td>69.5</td>
<td>0.822 (0.34)</td>
<td>0.636 (0.19)</td>
<td>2.908 (1.57)</td>
<td>-0.753 (0.75)</td>
<td>-0.5 (10.0 to 11.4)</td>
</tr>
<tr>
<td>Tibballs58</td>
<td>SYS v EDU</td>
<td>23.4</td>
<td>-1.186 (0.53)</td>
<td>0.187 (0.10)</td>
<td>-0.040 (0.03)</td>
<td>0.453 (0.57)</td>
<td>11.9 (-18.4 to 42.1)</td>
</tr>
<tr>
<td>Khatib66</td>
<td>EDU v FED</td>
<td>86.2</td>
<td>1.836 (0.17)</td>
<td>-2.051 (0.26)</td>
<td>2.185 (0.52)</td>
<td>2.549 (0.29)</td>
<td>65.8 (58.6 to 73.0)</td>
</tr>
<tr>
<td>Jagg*</td>
<td>Unclear intervention details</td>
<td>19.5</td>
<td>-1.420 (0.26)</td>
<td>0.080 (0.02)</td>
<td>-0.006 (0.03)</td>
<td>-0.586 (0.34)</td>
<td>-14.8 (-33.1 to 3.6)</td>
</tr>
<tr>
<td>Arrellino67</td>
<td>FED v GOAL</td>
<td>7.6</td>
<td>-2.493 (0.15)</td>
<td>-0.088 (0.133)</td>
<td>0.649 (0.235)</td>
<td>3.046 (0.68)</td>
<td>45.4 (38.5 to 52.3)</td>
</tr>
<tr>
<td>Arrellino67</td>
<td>FED v GOAL</td>
<td>29.0</td>
<td>-0.895 (0.04)</td>
<td>0.122 (0.10)</td>
<td>-0.109 (0.08)</td>
<td>2.267 (0.14)</td>
<td>74.9 (65.5 to 84.4)</td>
</tr>
<tr>
<td>Salmon63†</td>
<td>No intervention</td>
<td>42.7</td>
<td>-0.295 (0.07)</td>
<td>0.003 (0.02)</td>
<td>0.021 (0.02)</td>
<td>0.485 (0.22)</td>
<td>17.9 (-0.3 to 36.2)</td>
</tr>
</tbody>
</table>

SYS = system change; EDU = education; FED = feedback; REM = reminders; SAF = institutional safety climate; INC = incentives; GOAL = goal setting; ACC = accountability; WHO-5 = combined intervention strategies including SYS, EDU, FED, REM, and SAF.

*Mean change in hand hygiene compliance during period after intervention period attributed to intervention accounting for baseline trends (see appendix 3 for details).

†Evidence of autocorrelation; Newey-West standard errors reported.

‡Hand hygiene compliance measured in student nurses.

Fig 5 | Forest plot showing effect size as mean log odds ratios for hand hygiene compliance for all direct pairwise comparisons from interrupted time series studies. Lee and colleagues** was a multi-centre study. In hospitals 8 and 9 baseline strategy was already equivalent to WHO-5. SYS = system change; EDU = education; FED = feedback; REM = reminders; SAF = institutional safety climate; INC = incentives; GOAL = goal setting; ACC = accountability; WHO-5 = combined intervention strategies including SYS, EDU, FED, REM, and SAF.
Hygiene, all components of the intervention were already in place in the baseline period.48

Twelve pairwise comparisons met the criteria for network meta-analysis, and included direct comparisons between all pairs of strategies except WHO-5 versus WHO-5+ and no intervention versus single intervention (fig 6). The network meta-analysis showed that although there was large uncertainty in effect sizes among the pairwise comparisons, point estimates for all intervention strategies indicated an improvement in compliance with hand hygiene compared with no intervention (fig 7). When two strategies, WHO-5 and WHO-5+, were compared with no intervention there was strong evidence that they were effective (table 2). The WHO5+ strategy also showed additional improvement compared with single intervention strategies and WHO-5 alone. For the latter comparison, which depended only on indirect comparisons, the estimated effect size was similar to that seen in the randomised controlled trials, though uncertainty was much larger (odds ratio for WHO-5 versus WHO-5+ was 1.82, 95% credible interval 0.2 to 12.2). WHO-5+ had the highest probability (67%) of being the best strategy in improving compliance (fig 8).

After we excluded studies with multiple stepwise interventions in the sensitivity analysis, there was a decrease in the effect size of all intervention strategies (appendix 4).

Clinical outcomes
Nineteen studies reported clinical or microbiological outcomes alongside hand hygiene outcomes. Six of these were multicentre studies,35 42 48 55 62 67 and 13 were based in a single hospital.28 30 46 47 49 52 56 57 59 63 66 69 All reported that improvements in hand hygiene were associated with reductions in at least one measure of hospital acquired infection and/or resistance rates. In most
case, however, either appropriate analysis was lacking, denominators were not reported, time series data were not shown (making interrupted time series designs vulnerable to pre-existing trends), or numbers were too small to draw firm conclusions.

There were, however, three single centre studies that did not have these limitations.\textsuperscript{49,57,61} Two of these studies, which lasted about seven years, used time series analysis to study associations between use of alcohol hand rub and clinical outcomes, with adjustment for changing patterns of antibiotic use.\textsuperscript{49,57} Lee and colleagues found strong evidence ($P<0.001$) that increased use of alcohol hand rub was associated with reduced incidence of healthcare associated infection and evidence that it was associated with reduced healthcare associated methicillin resistant \textit{Staphylococcus aureus} (MRSA) infection ($P=0.02$).\textsuperscript{49} Vernaz and colleagues found strong evidence that increased use of alcohol based hand rub was associated with reduced incidence of MRSA clinical isolates per 100 patient days ($P<0.001$), reporting that 1L of hand rub per 100 patient days was associated with a reduction in MRSA of 0.03 isolates per 100 patient days.\textsuperscript{57} No association was found between increased use of alcohol based hand rub and clinical isolates of \textit{Clostridium difficile}. Johnson and colleagues reported that an intervention in an Australian teaching hospital associated with a mean improvement of compliance with hand hygiene from 21\% to 42\% was also associated with declining trends in clinical MRSA isolates (by 36 months after the intervention clinical isolates per discharge had fallen by 60\% compared with the baseline before the intervention), declining trends in MRSA bacteraemias (57\% lower than baseline after 36 months), and declining trends in clinical isolates of extended spectrum \textit{$\beta$ lactamases} (ESBL) producing \textit{E coli} and \textit{Klebsiella} (>90\% below baseline 36 months after intervention), though there was no evidence of changes in patient MRSA colonisation at four or 12 months after the intervention.\textsuperscript{63}

In addition to hand hygiene, however, the intervention included patient decolonisation and ward cleaning, and the relative importance of these measures cannot be determined.

Among the multicentre studies, Grayson and colleagues described a similar hand hygiene intervention (but without additional decolonisation or ward cleaning) initially introduced to six hospitals as a pilot study and, later, to 75 hospitals in Victoria, Australia, as part of a state-wide roll out.\textsuperscript{62} Both the pilot and roll out were associated with large improvements in compliance (from about 20\% to 50\%) and similar clinically important trends after the intervention for reduced MRSA bacteraemias and MRSA clinical isolates per patient discharge (though in the state-wide roll out hospitals there was also a decline in MRSA clinical isolates before the intervention that continued after the intervention).

Roll out of a similar hand hygiene intervention (the Cleanyouhands campaign, based on WHO-5) in England and Wales was reported to be associated with reduced rates of MRSA bacteraemia (from 1.9 to 0.9 cases per 10 000 bed days) and \textit{C difficile} infection (from 16.8 to 9.5 cases per 10 000 bed days), but no association was found with methicillin-sensitive \textit{S aureus} (MSSA) bacteraemia.\textsuperscript{50} This study also reported independent associations between procurement of alcohol hand rub and MRSA bacteraemias; in the last 12 months of the study, MRSA bacteraemias were estimated to have fallen by 3\% (95\% confidence interval 5\% to 15\%) for each additional mL of hand rub used per bed day (adjusted for other interventions and hospital level mupirocin use, a surrogate marker for MRSA screening and decolonisation). Similarly, each additional mL of soap used per bed day was associated with a 0.7\% (0.4\%, 1.0\%) reduction in \textit{C difficile} infection.

Benning and colleagues described the evaluation of a separate but contemporaneous patient safety intervention that included a hand hygiene component in nine English hospitals with nine matched controls.\textsuperscript{57} Both intervention and control sites experienced large increases in consumption of soap and alcohol hand rub between 2004 and 2008 and substantial falls in rates of MRSA and \textit{C difficile} infection, though in all cases (soap, hand rub, and infections) there was no evidence that differences between intervention and control sites resulted from anything other than chance.

In a two year study in 33 surgical wards in 10 European hospitals, Lee and colleagues found that, after adjustment for clustering, potential confounders, and temporal trends, enhanced hand hygiene alone was not associated with a reduction in MRSA clinical cultures and MRSA surgical site infections, and neither was a strategy of screening and decolonisation, but in wards where both interventions were combined, there was a reduction in the rate of MRSA clinical cultures of 12\% per month (adjusted incidence rate ratio 0.88, 95\% confidence interval 0.79 to 0.98).\textsuperscript{48}

Among the randomised controlled trials, Mertz and colleagues found similar rates of hospital acquired MRSA colonisation in intervention and control groups (0.73 v 0.66 events per 1000 patient days, respectively; $P=0.92$), though adherence to hand hygiene was only 6\% higher in the intervention arm.\textsuperscript{35} Finally, in a study in 13 European intensive care units, Derde and colleagues reported a declining trend in acquisition of antimicrobial resistant bacteria (weekly incidence rate ratio 0.976, 95\% confidence interval 0.954 to 0.999) associated with a hand hygiene intervention that increased compliance from about 50\% to over 70\%.\textsuperscript{42} The decline was largely because of reduced MRSA acquisition. The intervention also included universal chlorhexidine body washing, and it is not possible to establish the relative importance of hand hygiene.

\textbf{Level of information on resource use}

Reporting of information on cost and resource use was limited, with 3, 26, and 12 studies classified as having high, moderate, and low information, respectively (appendix 8). Three studies reported costs associated with both materials and person time\textsuperscript{28,52,62}; in two cases these reports were in separate papers.\textsuperscript{29,71} Table 4 summarises the reported costs of interventions.
Table 4. Extracted data on resource use in studies of interventions to improve hand hygiene in healthcare workers

<table>
<thead>
<tr>
<th>Author contact</th>
<th>Team and leader directed strategies: alcohol hand rub, website, leaflets, posters, newsletters, article in hospital magazines</th>
<th>Reinforcement</th>
<th>Phase I: None (with AHR); phase II: WHO-5</th>
<th>WHO-5 (except institutional safety climate)</th>
<th>Feedback + goal-setting + reminders + education</th>
<th>System change + reminders (with AHR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mestre (2012), ITS</td>
<td>N/A</td>
<td>Reinforcement</td>
<td>WHO-5</td>
<td>feedback. Phase II: WHO-5</td>
<td>WHO-5 (intense)</td>
<td>System change + feedback + reminders (with AHR)</td>
</tr>
<tr>
<td>Higgins (2013), ITS</td>
<td>Paper 165 600 450 365 1008.2</td>
<td>WHO-5 System change</td>
<td>reminders (with AHR)</td>
<td>System change</td>
<td>feedback + reminders (with AHR)</td>
<td>System change + feedback + reminders (with AHR)</td>
</tr>
<tr>
<td>Coren (2011), ITS</td>
<td>Paper 50 000 17 630 4668.5</td>
<td>WHO-5</td>
<td>feedback + reminders (with AHR)</td>
<td>WHO-5</td>
<td>feedback + reminders (with AHR)</td>
<td>WHO-5</td>
</tr>
<tr>
<td>Armellino (2012), ITS</td>
<td>Research assistant for audit and training 1.79 FTE (287 hours) assuming salary as £2500 per month</td>
<td>System change</td>
<td>feedback + reminders (with AHR)</td>
<td>WHO-5</td>
<td>feedback + reminders (with AHR)</td>
<td>WHO-5</td>
</tr>
<tr>
<td>None (unclear AHR use) USA, 2008 21 video cameras N/A Paper 50 000 17 630 4668.5</td>
<td>Research assistant for audit and training 1.79 FTE (287 hours) assuming salary as £2500 per month</td>
<td>System change</td>
<td>feedback + reminders (with AHR)</td>
<td>WHO-5</td>
<td>feedback + reminders (with AHR)</td>
<td>WHO-5</td>
</tr>
<tr>
<td>None (unclear AHR use) USA, 2003-6 Prizes as candy, chocolate bars, pizza, and others</td>
<td>Author contact</td>
<td>System change</td>
<td>feedback + reminders (with AHR)</td>
<td>WHO-5</td>
<td>feedback + reminders (with AHR)</td>
<td>WHO-5</td>
</tr>
<tr>
<td>None (unclear AHR use) USA, 2008-9 Cost for marketing consultancy N/A Author contact</td>
<td>Author contact</td>
<td>System change</td>
<td>feedback + reminders (with AHR)</td>
<td>WHO-5</td>
<td>feedback + reminders (with AHR)</td>
<td>WHO-5</td>
</tr>
</tbody>
</table>

Discussion

**Principal findings**

A multi-faceted hand hygiene intervention—WHO-5—and single interventions including system change, training and education, or reminders alone are associated with improved compliance with hand hygiene among healthcare workers in hospital compared with standard practice. Results from both randomised controlled trials and interrupted time series designs provide consistent evidence that adding supplemental interventions including goal setting, reward incentives, and accountability to the WHO-5 strategy lead to additional improvements in compliance. Information about resources used in the interventions was not well reported.

**Comparison with other studies**

We are aware of four previous systematic reviews of interventions for hand hygiene in healthcare settings.5–8 One of these found only four studies of sufficient methodological quality to reliably evaluate interventions to promote hand hygiene and was unable to reach firm conclusions.5 Overlap between included studies in the other three and our review is small: respectively four (9.8%),8 three (7.3%),6 and five (12.2%)7 of studies included in our review were included in previous reviews, while 17 (80.1%), 38 (92.7%), and 40 (88.9%) of the studies in these reviews failed to meet the minimum quality threshold in ours.12,13 While high quality non-randomised studies can potentially play an important role in the evaluation of interventions if they are analysed with appropriate methods, there are many reasons for thinking that simple before-after studies (a design used by most of the studies included in previous reviews) do not provide a reliable basis for evaluating interventions.72–74 While an interrupted time series study (where multiple outcome measures are taken before and after the intervention) represents a strong quasi-experimental design, a before-after study compares a single outcome measure before and after the intervention and is vulnerable to distorting effects of pre-existing trends.

We found an increasing number of “high quality” studies on interventions for hand hygiene after 2009. From two previous systematic reviews5–6 examining the literature from 1980 to November 2009, we found only 10 studies meeting the EPOC criteria (one randomised controlled trial, eight interrupted time series, and one controlled before-after study). With the same criteria, our review found 31 studies (five randomised controlled trials, 24 interrupted time series, one non-randomised trial, and one controlled before-before study) published between December 2009 and February 2014.

Reporting on resource implications for interventions was generally limited with some notable exceptions. Most included studies reported only part of the resources used, and methods for collecting cost data were unclear. Such information on resource use is important both for those wishing to implement similar strategies and for economic evaluation of different interventions.10,75 A good framework to collect such...
data has also been proposed. Cost effectiveness analysis of promotion of hand hygiene is required to assess under what circumstances these initiatives represent good value for money and when resources might be better directed at supplemental interventions, including care bundles, ward cleaning, and screening and decolonisation, to complement well maintained compliance with hand hygiene.

Strengths and limitations of study
A particular strength of our study is that the network meta-analysis allowed us to quantify the relative efficacy among a series of different intervention strategies with different baseline interventions, even where the direct head-to-head comparisons were absent.

This study also has several limitations. Firstly, details on implementation of components of the intervention varied substantially. For example, personal feedback and group feedback were classified together, but, in practice, the impacts of these strategies can vary. Moreover, different studies might implement the same programme with different quality of delivery and level of adherence, so called intervention fidelity or type III error. Both issues are common to many interventional studies with more components tend to perform better when the effects vary between study arms intervention periods. Thirdly, it is possible that if the novelty of the intervention itself that leads to improvements in compliance and that any sufficiently novel intervention would do the same regardless of the components used. This clearly cannot be ruled out and is not necessarily inconsistent with our findings that interventions with more components tend to perform better. At present, however, there are too few high quality studies to evaluate whether individual components of interventions show consistent differences that cannot be explained by novelty alone. Fourth, results might be distorted by publication bias. Fifth, there might also be a low level of language bias because we excluded studies in languages other than English. The magnitude of such bias, however, is likely to be small.

Finally, linking improved compliance to clinical outcomes such as number of infections prevented would provide more direct evidence about the value of such interventions. Such direct evidence is still limited in hospital settings, as interventions supported by a growing body of indirect evidence as well as biological plausibility. Moreover, findings from studies included in our review that reported clinical or microbiological outcomes are consistent with substantial reductions in infections for some pathogens, such as MRSA, resulting from large improvements in hand hygiene. The lack of a measureable effect of improved hand hygiene on MSSA infections might seem paradoxical but can be partly explained by the fact that MSSA infections are more likely to be of endogenous origin, whereas MRSA is more often linked to nosocomial cross transmission. Moreover, predictions from modelling studies that hand hygiene will have a disproportional effect on the prevalence of resistant bacteria in hospitals (provided resistance is rare in the community) seem to have been borne out in practice.

Conclusions
While there is some evidence that single component interventions lead to improvements in hand hygiene, there is strong evidence that the WHO-5 intervention can lead to substantial, rapid, and sustained improvements in compliance with hand hygiene among healthcare workers in hospital settings. There is also evidence that goal setting, reward incentives, and accountability provide additional improvements beyond those achieved by WHO-5. Important directions for future work are to improve reporting on resource implications for interventions, increasingly focus on strong study designs, and evaluate the long term sustainability and cost effectiveness of improvements in hand hygiene.

We are grateful to all authors of the literature included in this review who responded to requests for additional information. We also thank the infection control staff of Sappasitphiprasong Hospital for technical support and Cecelia Favede for help in editing.

Contributors. NL, BSC, YL, DL, NG, and ND contributed to the study conception and design. NL and BSC extracted data, and NL performed the data analysis. NL wrote the first draft. DL, YL, MH, ASL, SH, NG, ND, and BSC critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript. NL and BSC are guarantors.

Funding. This research was part of the Wellcome Trust-Mahidol University-Oxford Tropical Medicine Research Programme supported by the Wellcome Trust of Great Britain (089275/Z/09/Z). BSC was supported by the Oak Foundation and the Medical Research Council and Department for International Development (grant No MR/K006924/1).

Competing interests. All authors have completed the ICMJE uniform disclosure form at http://www.icmje.org/coi_disclosure.pdf and declare no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval. Not required
Data sharing. The relevant data and code used in this study are available from the authors.

Transparency. The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

This is an Open Access article distributed in accordance with the terms of the Creative Commons Attribution (CC BY 4.0) license, which permits others to distribute, remix, adapt and build upon this work, for commercial use, provided the original work is properly cited. See: http://creativecommons.org/licenses/by/4.0/.


64 Khatib M, Jamaleddine G, Abdallah A, Ibrahim Y. Hand washing and
62 Grayson ML, Jarvie LJ, Martin R, et al. Significant reductions in
75 Graves N, Halton K, Lairson D. Economics and preventing
73 Davey P, Brown E, Charani E, et al. Interventions to improve antibiotic
72 Ansari F, Grey K, Nathwani D, et al. Outcomes of an intervention to
69 Marra AR, Guastelli LR, de Araújo CM, et al. Positive deviance: a new
68 Gould D, Chamberlain A. The use of a ward-based educational
2008;2;188:633-40.
2008,2;188:633-40.
2011;342:d199.
2010;31:12-20.
20013;97:1938-43.
2006;21(suppl 2):S35-42.
2002;31:115-23.
2010;97:1938-43.
2012;28:138-44.
2014;23:6,750-6.
2014;23:e2.
2010;31:12-20.
2006;2;188:633-40.
2011;342:d199.
2010;31:12-20.
20013;97:1938-43.
2014;23:e2.
2010;31:12-20.
20013;97:1938-43.
2014;23:e2.