healthier scotland
SCOTTISH GOVERNMENT

Health Protection Scotland

NHS National Services Scotland

NHS Scotland MRSA Screening Pathfinder Programme

Final Report Volume 2: An assessment of the Economics, Implementation and Modelling of Universal MRSA Screening

Prepared for the Scottish Government HAI Task Force
by Health Protection Scotland

Delivered December 2009
Published February 2011

NHS Ayrshire & Arran

NHS Grampian

NHS Eileanan Siar Western Isles

Acknowledgements

This report would not have been completed successfully and within schedule without the cooperation and support of the staff in all of the participating Pathfinder hospitals. Their collaboration is gratefully acknowledged.

Final Report delivered to SGHD in December 2009

First published in February 2011

ISBN 978-1-873772-33-1

For all enquiries please contact:

HAI & IC Group
1 Cadogan Square
Cadogan Street
Glasgow
G2 7HF

Tel: 0141 300 1100
Fax: 0141 300 1170

Email: nss.hps.enquires@nhs.net

Reference this report as:

Health Protection Scotland, National Services Scotland, NHS Scotland MRSA Screening Pathfinder Programme Final Report Volume 2: An Assessment of the Economics, Implementation and Modelling of Universal Screening 2011, Health Protection Scotland [Report]

Designed and typeset by:

Graphics Team, Health Protection Scotland

1 Executive Summary

The development of, and results from, an economic model were described within the NHS Quality Improvement Scotland 2007 HTA report – The clinical and cost effectiveness of screening for meticillin resistant *Staphylococcus aureus* (MRSA). This cost consequence analysis model was presented with the costs of the different screening strategies and the number of infections avoided. Development of this model was constrained by the lack of robust evidence for key variables in the infection control literature. The NHS QIS HTA recommended model strategy 2, which proposed universal screening for all patients using direct chromogenic agar testing. This required the lowest investment and provided the best outcome as a result of that investment.

Many of the assumptions and parameters used in constructing the NHS QIS HTA model were not confirmed by the findings of the Pathfinder project. The model was re-worked, using observed data, in order to better represent the observations found in the Pathfinder Boards.

Although only one quarter of elective admissions attended pre-admission clinics, virtually all of those who did attend were screened (98% compliance). Screening uptake within the study overall was found to be 85%. The main reason for patients not being screened was that they had been discharged before the screen was taken. Uptake of screening by patients who were offered it was high (0.04% refusal rate).

Median turnaround time for laboratory confirmation of colonisation within the study was 48 hours, and 28 hours for negative samples. Within the pathfinder project two thirds of admissions (for both under and over 65s) were admitted to 'high risk' specialties as defined by the HTA, and one third to 'low risk' specialties. This was significantly different to the original HTA model estimates. No difference was found in incidence of infection in high risk or low risk specialty admissions and prevalence of colonisation on admission was in fact found to be higher within low risk specialties. All of these findings differed from the original HTA model assumptions. Patient movement within the hospital between specialties during a single admission was such that defining infection risk by admission speciality was not appropriate.

Seventy-four percent of admissions who were pre-emptively isolated due to presumed colonisation on admission had a confirmed colonisation status, indicating that clinical risk assessment, even as currently practised, has a part to play in allocating patients correctly to isolation. This is the subject of a special study within this programme.

Less than half of the admissions found to be positive were commenced on decolonisation therapy. However, only 3% of these patients were able to complete the course (i.e. were deemed negative during their stay), representing only one in 33 (3.1%) of all patients who screened MRSA positive. This poor compliance was largely

due to a median length of stay of three days. Specialties with longer average lengths of stay were better placed to both decolonise and isolate colonised patients.

Availability of single (isolation) rooms varied from specialty to specialty, as did MRSA colonisation prevalence; however, availability of isolation facilities did not necessarily match the requirement for them. During the year of the pathfinder project, just under half of those patients screening positive were isolated at some point during their stay. Many patients were not isolated or cohorted, because they were in hospital for less than two days and their MRSA colonisation status was not known until after discharge. Of those patients who screened positive on admission, that were not started on decolonisation during their stay, two thirds were discharged before their results were returned.

Service redesign in acute care should be considered in order to maximise the potential of the above noted interventions to reduce risk of MRSA infection for patients during a hospital stay. Reduced turnaround times may also have a role to play in ensuring practice is clinically effective, however there is limited evidence regarding the effectiveness of rapid microbiology diagnostic tests (e.g. PCR (laboratory or near patient testing) in reducing actual transmission of MRSA; currently, these tests are considerably more expensive than chromogenic agar. The time required for clinical risk assessment is not as great as the HTA assumed; the modelled time differential between universal laboratory test screening and clinical risk assessment was a significant factor in rejecting the latter within the HTA.

The reworked model, populated with the parameters found within the pathfinder study, projected a reduction in MRSA colonisation over three to five years to low endemic levels (0.5-1.8%). Little difference was seen in the modelled effectiveness of using PCR versus chromogenic agar over this time frame. This is primarily due to the limited availability of isolation facilities. A faster turn around time does not affect the availability of single rooms.

The Pathfinder project was undertaken over the period of one year and was designed as an implementation study. Discretion must be used in interpreting the results of the modelling, and primary consideration must be given to the Pathfinder cohort study measured against the principles of public health as a source for intelligence on which to make policy decisions.

2 Table of Contents

1 Executive Summary i

2 Table of Contents iii

3 List of Figures viii

4 List of Tables ix

5 Background 1

6 Introduction 3

6.1 Tasks within Aim 2 4

7 Methods 5

7.1 Task 1: Objective 1-14: To analyse the data collected within the Pathfinder project and compare these to the estimates derived from the literature which were used within the NHS QIS HTA 5

7.2 Modelling approach used within the NHS QIS HTA 8

7.2.1 Description of the model 8

7.3 Task 2: To re-populate the model produced during the NHS QIS HTA using the parameters collected within the Pathfinder project 11

7.4 Task 3: To review the overall effect on the outcomes and compare the model output to the effect found within the Pathfinder Boards 11

7.5 Task 4: To alter the model using the knowledge gathered during the Pathfinder Project 11

7.6 Task 5: To consider the implications and cost predictions of the model compared to the findings of the Pathfinder project and consider the implications for MRSA screening in NHSScotland 12

8 Assumptions 13

9 Results to address Aim 2 17

9.1.1 Aim 2 Objective 1: To identify the proportion of elective admissions who attend pre-assessment clinics and the proportion that were screened and the reasons for not screening 17

9.1.2 Aim 2 Objective 2: To identify the proportion of emergency admissions and specialty transfer (between hospitals) who were screened on admission. 20

9.1.3 Aim 2 Objective 3: To monitor the turnaround time (TAT) for reporting from sample collection to reporting by laboratories and where the potential delays are. 23

9.1.4 Aim 2 Objective 4:To identify the proportion of admissions with a positive MRSA screen identified at a pre-assessment clinic who were not subsequently admitted as planned 28

9.1.5 Aim 2 Objective 5:To identify the proportion of admissions screened for MRSA who were admitted to high-risk and low-risk specialty wards 29

9.1.6 Aim 2 Objective 6:To evaluate the proportion of those admissions pre - emptively isolated who subsequently were identified as MRSA positive. 32

9.1.7 Aim 2 Objective 7:To evaluate the proportion of MRSA positive admissions who receive decolonisation. 33

9.1.8 Aim 2 Objective 8:To evaluate the distribution of patient length of stay by specialty i.e. who can be screened and treated. 35

9.1.9 Aim 2 Objective 9:To describe the number of single bed rooms available per ward. 38

9.1.10 Aim 2 Objective 10:To evaluate the proportion of admissions identified as colonised who were isolated or cohorted. 39

9.1.11 Aim 2 Objective 11:To describe the reasons for not isolating colonised patient admissions 42

9.1.12 Aim 2 Objective 12:To evaluate the proportion of admissions identified as colonised and successfully decolonised and the reasons for not decolonising admissions with a positive screen. 42

9.1.13 Aim 2 Objective 13:To describe the reasons why all inpatient admissions were not screened. 43

9.1.14 Aim 2 Objective 14/15:To examine the potential for new technologies or approaches to offer better value for money 46

9.1.15 Aim 2 Objective 16:To quantify the time taken to carry out swab screening versus clinical risk assessment for MRSA colonisation 47

9.1.16 Aim 2 Objective 17:To carry out an economic analysis of the cost effectiveness of the programme in the context of other possible interventions to reduce MRSA in NHSScotland 48

10 Comparison of NHS QIS HTA model with Pathfinder results 49

10.1 Economic parameters update 51

10.1.1 Staff costs 51

10.1.2 Patient swabbing 51

10.2 Laboratory tests 51

10.2.1 Screening agar and chromogenic agar testing 51

10.2.2 Real-time PCR 52

10.2.3 Contact precautions 52

10.2.4 Costs associated with inpatient stay 52

10.2.5 Decolonisation treatment 53

11 Discussion 68

11.1.1 Aim 2 Objective 1:To identify the proportion of patients admitted electively who attend pre-assessment clinics and the proportion that were screened and the reasons for not screening 68

11.1.2 Aim 2 Objective 2:To identify the proportion of emergency admission and specialty transfer (between hospitals) patients who were screened on admission. 69

11.1.3 Aim 2 Objective 3:To monitor the turnaround time (TAT) for reporting from sample collection to reporting by laboratories and where the potential delays are. 70

11.1.4 Aim 2 Objective 4:To identify the proportion of patients with a positive MRSA screen identified at a pre-assessment clinic who were not subsequently admitted as planned. 71

11.1.5 Aim 2 Objective 5:To identify the proportion of patients screened for MRSA who were admitted to high-risk and low-risk specialty wards 72

11.1.6 Aim 2 Objective 6:To evaluate the proportion of those patients pre - emptively isolated who subsequently were identified as MRSA positive 73

11.1.7 Aim 2 Objective 7:To evaluate the proportion of MRSA positive patients who receive decolonisation treatment. 74

11.1.8 Aim 2 Objective 8:To evaluate the distribution of patient length of stay by specialty i.e. who can be screened and treated. 75

11.1.9 Aim 2 Objective 9:To describe the number of single bed rooms available per ward 75

11.1.10 Aim 2 Objective 10:To evaluate the proportion of patients identified as colonised who are isolated, cohorted or separated 76

11.1.11 Aim 2 Objective 11:To describe the reasons for not isolating colonised patients 78

11.1.12 Aim 2 Objective 12:To evaluate the proportion of patients identified as colonised and not decolonised and the reasons for this 78

11.1.13 Aim 2 Objective 13:To describe the reasons why all inpatient admissions were not screened 79

11.1.14 Aim 2 Objective 14:To identify new technologies 79

11.1.15 Aim 2 Objective 15:To examine the potential for new technologies or approaches to offer better value for money 81

11.1.16 Aim 2 Objective 16:To quantify the staff time taken to carry out screening for MRSA colonisation (versus previous risk assessment time) 82

11.1.17 Aim 2 Objective 17:To carry out an economic analysis of the costs effectiveness of the programme in the context of other possible interventions to reduce MRSA in NHSScotland 83

11.2 Task 2:To re-populate the model produced during the NHS QIS HTA using the parameters collected within the Pathfinder project 84

11.3 Task 3: Review the overall effect on the outcomes and compare the model output to the effect found within the Pathfinder Boards 84

11.4 Task 4:To alter the model taking into account the assumptions made in the design of the model and to use the knowledge gathered during the Pathfinder Project in order to ensure the model design is robust and based on health service reality 85

11.5 To consider the implications and cost predictions of the model compared to the findings of the Pathfinder project and consider the implications for MRSA screening in NHSScotland 85

12 Recommendations 87

13 Limitations of the study/modelling 88

14 Reference List 89

15 Appendix 1: MRSA Screening Economic Model 93

15.1 Summary of review of economic model approach 93

15.2 Key findings and recommendations 93

15.3 Methodology 94

15.3.1 Operating Constraints 97

15.3.2 Testing and Validation 98

15.3.3 Sensitivity Analysis 98

15.3.4 Model Constraints 99

15.3.5 Documentation 99

15.3.6 Nature of the data 100

15.3.7 Methodology Summary 101

15.4 Model Architecture 102
15.4.1 Existing model 102
15.4.2 Model revisions 103
15.4.3 Major revisions 104
15.4.4 Minor revisions 106
15.4.5 Further improvements 107
15.5 Commentary and recommendations 108
16 Acronyms 110
17 Glossary 111

3 List of Figures

Figure 7-1: Description of the recommended Strategy 2 patient pathway: test all admissions 10

Figure 9-1: Turnaround time for positive result swabs 23

Figure 9-2: Turnaround time for negative swabs 24

Figure 9-3: Turnaround time for positive results by Pathfinder Board 24

Figure 9-4: Turnaround time for negative samples by Pathfinder Board 25

Figure 9-5: Box and whisker plot showing the time from admission to swab being taken by Pathfinder Board 28

Figure 9-6: Histogram showing length of stay by days. N=80,641 for combined Pathfinder Boards 35

Figure 9-7: Proportion of total admissions screened by specialty 38

Figure 9-8: Percentage of total admissions with known admission specialty which were missed by specialty 45

Figure 9-9: Percentage of total admissions missed with known length of stay by length of stay 46

Figure 10-1: Change in percentage prevalence over time for Strategy 1 (no screening) set as a baseline compared with Strategy 2 for ChromChrom and Chrom PCR for tertiary referral hospital and Pathfinder data for year one 62

Figure 10-2: Change in percentage prevalence over time for Strategy 1 (no screening set as a baseline) compared with Strategy 2 for ChromChrom and Chrom PCR for large general hospital 63

Figure 15-1: Simplified development process 94

Figure 15-2: Simplified representation of a decision making process leading to a go/no-go outcome 95

Figure 15-3: Decision tree structure associated with Strategy 1 102

4 List of Tables

Table 6-1: Pathfinder programme objectives relating to Aim 2 3

Table 7-1: Comparison in study methodology between NHS QIS HTA model and pathfinder outlining where differences in approach were known on initiation of the Pathfinder Project 5

Table 7-2 Laboratory test combinations tested within the NHS QIS HTA model 9

Table 7-3: List of changes made to model structure 12

Table 8-1: Assumptions made in the development of the NHS QIS HTA model Strategy 2 which have not been addressed during the Pathfinder Project. 13

Table 9-1: Number and percentage of elective patient admissions identified as MRSA positive by screen at pre-assessment clinic, by pathfinder board 17

Table 9-2: Results of multivariable clustered logistic regression analyses of being screened at pre-admission among the N= 6,448 admissions who were screened during the study period 18

Table 9-3: Number and percentage of admissions, and number and percentage screened among the N= 6,448 elective admissions attending pre-admission during the study period 19

Table 9-4: Results of multivariable clustered logistic regression analyses of being screened among the N=57,121 emergency admissions, and specialty transfer between hospitals, during the study period 21

Table 9-5: Number and percentage of admissions, and number and percentage screened among the N=57,121 emergency admissions, and specialty transfer between hospitals during the study period 22

Table 9-6: Median and percentiles of turn around time (TAT) for time admission screen taken to availability of result by pathfinder board 26

Table 9-7: Results of multivariable clustered linear regression analyses of time (in log hours) from swab taken to result returned to ward among the N=62,694 admissions for whom this was known, during the study period 27

Table 9-8: Number and percentage of admissions by location of screen taken and high risk or low risk specialty. N=81,388 (Only admissions with specialty of admission are included within these analyses) 29

Table 9-9: Number and percentage of all admissions MRSA positive on admission to hospital, by high risk specialty during the study period 30

Table 9-10: Number and percentage of all admissions MRSA positive on admission to hospital, by low risk specialty during the study period 31

Table 9-11: Number of admissions going to a high risk and low risk specialty ward by age category over 65 and under 65s 32

Table 9-12: Number of admissions pre-emptively isolated or cohorted by their screening result and history of MRSA by hospital and NHS Board 33

Table 9-13: Number and percentage of MRSA positive patient admissions receiving decolonisation as a result of admission screen, by health board during the study period 33

Table 9-14: Descriptive statistics for length of stay by Pathfinder Board 35

Table 9-15: Length of stay (days) by specialty of admission among N=80,614 admissions for whom length of stay was known, during the study period 36

Table 9-16: Number of single rooms available per ward in pathfinder hospitals and NHS Boards 38

Table 9-17: Number and percentage of MRSA positive admissions isolated, cohorted or separated during admission, by health board during the study period 39

Table 9-18: Results of multivariable clustered logistic regression analyses of being isolated (or cohorted) among N=1,303 admissions who screened positive on admission, during the study period 40

Table 9-19: Number and percentage of admissions, and number and percentage isolated (or cohorted) among N=2717 admissions who screened positive on admission during the study period 41

Table 9-20: Reasons where recorded for MRSA positive patient admissions being moved from isolation or cohort during the study period 42

Table 9-21: Reasons for patient admissions not receiving decolonisation treatments during the study period August 2008 – July 2009, for those positive admissions where reason for not decolonising was recorded 43

Table 9-22: Number and percentage of admissions, and number and percentage screened among the hospitals and health boards during the study period 44

Table 9-23:Those admissions not screened and the reasons for not screening for those admissions where this was recorded 44

Table 9-24: Comparison of test types 46

Table 9-25: Descriptive statistics for time taken in seconds for clinical risk assessment, nasal swabbing and full body swabbing 47

Table 9-26: Balance sheet Comparison of Current policy of targeted screening and Universal screening 48

Table 10-1: Assumptions made in the development of the NHS QIS HTA model Strategy 2 and subsequent findings during the Pathfinder Project. 49

Table 10-2: Costs associated with taking patient swab samples 51

Table 10-3: Cost per sample 52

Table 10-4: Costs associated with contact precautions 52

Table 10-5: Additional daily costs associated with single rooms 52

Table 10-6: Decolonisation resource requirement 53

Table 10-7: Comparison of size of hospitals with NHSQIS HTA and Pathfinder Project 53

Table 10-8: Parameter values common to both tertiary referral hospitals and large general hospital settings used in NHS QIS HTA and parameters collected from Pathfinder Project 54

Table 10-9: Parameter values specific to tertiary referral hospitals used in NHS QIS HTA and parameters collected from Grampian Health Board during the Pathfinder Project 56

Table 10-10: NHS QIS HTA table 6-18: Parameter values specific to large general hospitals referral hospitals used in NHS QIS HTA and parameters collected from Pathfinder Project 58

Table 10-11: NHS QIS HTA Table 6-25 Summary of results of sensitivity analysis- assumed large tertiary referral hospital i.e. Aberdeen Royal Infirmary 60

Table 10-12: MRSA infections predicted each year from each strategy for tertiary referral hospital 64

Table 10-13: MRSA infections predicted each year from each strategy for large general hospital with Strategy 1 as the baseline 65

Table 10-14: Number of infections prevented each year from each strategy for tertiary referral hospital 65

Table 10-15: Number of infections prevented each year from each strategy for large general hospital 66

Table 10-16: Summary of results for a tertiary referral hospital using Strategy 1 and Strategy 2 using ChromChrom and ChromPCR 66

Table 10-17: Summary of results for a large general hospital using Strategy 1 and Strategy 2 using ChromChrom and ChromPCR 67

Table 15-1: Deployment of strategies 97

This page has been intentionally left blank

5 Background

For a detailed background to the MRSA Screening programme please refer to Volume1 Clinical Effectiveness of MRSA screening.

This report combines the findings of the Pathfinder Project with the economic analysis undertaken in the model. The report includes a detailed record of the assumptions made within the model and a comparison of the differences in the parameters used to populate the model and those observed in the Pathfinder Project. This has been recorded as "lessons learned" during the Pathfinder Project with the understanding that this learning will be useful for any future modelling work undertaken in the field of MRSA screening. The limitations of the model are detailed and it is noted it was not designed to make any predictions on MRSA colonisation, cost or resource planning, rather to allow a comparison for policy and decision makers of various approaches in the absence of real world control.

In the course of undertaking the NHS QIS HTA it was apparent that there was not sufficient literature published to allow a full assessment of the validity of MRSA screening strategies. A modelling methodology was implemented which would allow a relative cost consequence analysis[1]. A unit of healthcare outcomes – the quality adjusted life year (QALY) is often used to measure the cost effectiveness of different interventions. The QALY allows comparisons of different interventions for a condition; and the relative effectiveness of interventions for a condition. At the time of the NHS QIS HTA it was not possible to assign such a utility value to MRSA infections (due to the fact MRSA infections present a wide range of different infection types with a great variation in morbidity and mortality).

A model was developed based on work undertaken by Cooper *et al* [1] who modelled isolation measures in the hospital management of MRSA. The model compared a variety of strategies, it made a large number of assumptions and estimated parameters based on a range of studies. The model was designed as a comparative tool in order to base a decision on which strategies should be considered for implementation. The model was not designed to be used as a predictive tool. The limitations and assumptions of this model were outlined within the NHS QIS HTA.

The NHS QIS HTA therefore recommended that a primary study should be set up within a whole NHS board area to assess whether screening all patients for MRSA is effective in preventing MRSA infection as predicted by the economic model. They also recommended that data from this study should be collected for at least a year to decide whether MRSA screening results in a reduction in prevalence of MRSA.

The Pathfinder project implemented the MRSA screening strategy 2 as recommended in the NHS QIS HTA [2] for one year and detailed data collection was undertaken in order to measure the parameters which were included within the HTA model, in practice in Scotland. Strategy 2 was to screen all inpatients and used a laboratory test for all screens. Within the

1 Cost Consequence Analysis: an economic evaluation comparing the costs and consequences of two or more alternative where costs and consequences are not aggregated, and all health outcomes are left in natural units

Pathfinder Project a set of objectives were described within Aim 2 – To test the estimates of the NHS QIS HTA economic model assumptions (Table 6-1). This volume of the Pathfinder report describes the findings of the Pathfinder project and the effect and implications these findings had on the output of the model.

The model presented was a stochastic compartment mass-action model developed using Simile (Simulistics Ltd™) a visual modelling platform. Full details of the model structure can be obtained from the HTA report and from the Simulistics website http://www.simulistics.com/projects/mrsa/index.htm.

The model tested a number of different combinations of microbiological test and screening strategies. The Pathfinder Project has been established using the recommendations from the HTA [2]; i.e. universal screening with chromogenic agar for all microbiological screening tests. The HTA model will therefore be populated using the updated parameter values and costs based on chromogenic agar being employed for all tests. Two of the original strategies (Strategy 1:do nothing and Strategy 2 using Chromogenic agar for both tests and Strategy 2 PCR for admission tests and Chromogenic agar for pre-admission tests) will be assessed by running the model and presenting results comparable to those within the NHS QIS HTA report.

The Pathfinder Project was an implementation study which was funded by the Scottish Government HAI Task Force for one year. There was no opportunity within the specification of the project to allow any "control" hospital where screening was undertaken to assess prevalence of colonisation in the absence of isolation and decolonisation. The study can only describe what was observed within that year of implementation. The scope of the project did not allow for collection of data for more than one year, therefore at the outset routinely available laboratory data were agreed as supplementary outcome measures for historical comparison. The re-population of the model was seen as crucial to the interpretation of the Pathfinder results as it would provide the opportunity to compare the observed effect of Strategy 2 (universal screening) against the "do nothing" option. It would also potentially provide some information around the potential impact of universal screening beyond the first year of implementation.

A number of limitations of the model have been identified both during the original development work and subsequently in re-populating the model. These limitations resulted in difficulties in obtaining accurate parameter estimates, modelling the nature of inpatient care and affected the intrinsic structure of the model. The Pathfinder Project should provide more accurate data for some parameters but the assumptions regarding transmission rates remain in the current model structure. These parameters are planned to be investigated by special research studies in 2010.

6 Introduction

This report presents the results of Aim 2: To test the estimates of the NHS QIS HTA economic model assumptions in Pathfinder Boards. The objectives of this section of the report were to gather information on the practical implementation of the Pathfinder Project and to provide estimates of the parameters required to re-populate the model. The objectives associated with aim two are described in Table 6-1. These objectives were delivered in order to fulfil the following programme tasks described later (see section 6.1). The parameters used to re-populate the model were gathered and are detailed within the results section of this report.

Table 6-1: Pathfinder programme objectives relating to Aim 2

	Objective
1	To identify the proportion of elective admissions who attend pre-assessment clinics and the proportion that were screened and the reasons for not screening
2	To identify the proportion of emergency admissions and specialty transfers (between hospitals) who were screened on admission
3	To monitor the turnaround time (TAT) for reporting from sample collection to reporting by laboratories and where the potential delays are
4	To identify the proportion of admissions with a positive MRSA screen identified at a pre-assessment clinic who were not subsequently admitted as planned
5	To identify the proportion of admissions screened for MRSA who were admitted to high-risk and low-risk specialty wards
6	To evaluate the proportion of those admissions pre-emptively isolated who subsequently were identified as MRSA positive
7	To evaluate the proportion of MRSA positive admissions who receive decolonisation treatment.
8	To evaluate the distribution of length of stay by specialty i.e. who can be screened and treated
9	To describe the number of single bed rooms available per ward
10	To evaluate the proportion of admissions identified as colonised who were isolated or cohorted
11	To describe the reasons for not isolating colonised patients
12	To evaluate the proportion of admissions identified as colonised and successfully decolonised and the reasons for not decolonising patients with a positive screen
13	To describe the reasons why all inpatient admissions were not screened.
14	To examine the potential for new technologies or approaches to offer better value for money
15	To identify new technologies
16	To quantify the time taken to carry out swab screening versus clinical risk assessment for MRSA colonisation
17	To carry out an economic analysis of the cost effectiveness of the programme in the context of other possible interventions to reduce MRSA in NHSScotland

6.1 Tasks within Aim 2

The work within Aim two comprised five main tasks:

1. Objective 1-14 To analyse the data collected within the Pathfinder project and compare these to the estimates derived from the literature which were used within the NHS QIS HTA
2. To re-populate the model produced during the NHS QIS HTA using the parameters collected within the Pathfinder project
3. To review the overall effect on the outcomes and compare the model output to the effect found within the Pathfinder Boards
4. To alter the model taking into account the assumptions made in the design of the model and to use the knowledge gathered during the Pathfinder Project in order to ensure the model design to reflect the healthcare environment in which MRSA screening takes place in NHSScotland
5. To consider the implications and cost predictions of the model compared to the findings of the Pathfinder project and consider the implications for MRSA screening in NHSScotland.

7 Methods

7.1 Task 1: Objective 1-14: To analyse the data collected within the Pathfinder project and compare these to the estimates derived from the literature which were used within the NHS QIS HTA

The methodology section described in Volume 1 of this report outlines both the methods employed in collecting data presented within this report and the approach to the analyses of these data [3].

The data collection and analysis is described in detail within the Pathfinder Project Interim Report [4] page 22-41.

Table 7-1 shows a comparison in study methodology between NHS QIS HTA model and pathfinder outlining where differences in approach were known on initiation of the Pathfinder project. The protocol for the Pathfinder Project was described in detail within the interim report [4], this was based on the recommendations of the NHS QIS HTA. There were some differences in the approach from the model to and the Pathfinder protocol and a comparison of the theoretical model protocol and the Pathfinder Project is detailed in Table 7-1.

Table 7-1: Comparison in study methodology between NHS QIS HTA model and pathfinder outlining where differences in approach were known on initiation of the Pathfinder Project

NHS QIS HTA	Pathfinder
Tertiary referral hospital and community population	Tertiary referral hospital and community population (Grampian) Two large general hospitals and community population (Ayrshire and Arran) Two small general hospitals and community population (Western Isles)
The community contains all prospective patients, both MRSA colonised and non-colonised	The community and other hospitals contain prospective patients, both MRSA colonised and non-colonised
Patients have two levels of readmission, with readmission being independent of whether or not they are MRSA colonised	Patients have two levels of readmission, with readmission being independent of whether or not they are MRSA colonised
Study population is adult inpatients	Study population is adult inpatients

NHS QIS HTA	Pathfinder
The single health board would include a tertiary referral hospital and a large general hospital	The Pathfinder project included a large tertiary referral hospital (Aberdeen Royal Infirmary and Woodend Orthopaedic Unit) and two general hospitals (Crosshouse and Ayr Hospitals) and two small general hospitals (Western Isles and Uist and Barra Hospital)
Cost calculations were undertaken for both a tertiary referral hospital and large general hospital	Parameters were measured within a tertiary referral hospital; two large general hospitals and two small general hospitals.
The following specialties were excluded: • Medical paediatrics • Surgical paediatrics • Obstetrics	The following specialties were excluded: • Medical paediatrics • Surgical paediatrics • Psychiatry • Obstetrics
Day case patients excluded	Day case patients excluded and patients with less than one overnight stay
Disaggregated into 2 patient groups: • Under 65 years • 65 years and over	Patients were not treated differently due to their age category, data was gathered on patient date of birth and therefore parameter estimates can be made by separating the Pathfinder population into: • Under 65 years • 65 years and over
Both age grouping mix in both the community and hospitals except in wards that are specifically occupied by over 65s only	Both age grouping mix in both the community and hospitals except in wards that are specifically occupied by over 65s only
Within the hospital specialist wards are grouped into high risk and low risk specialty wards for the tertiary referral hospital two out of the 15 high risk specialty wards and three out of the 19 low risk specialty wards were assumed to be occupied by over 65s only and the remaining wards were occupied by both age groups.	Patient placement varies due to a range of conflicting requirements from a patient and organisational perspective in reality this was expected to vary throughout the study period. High risk and low risk specialties defined by the NHS QIS HTA were not the same as the Pathfinders. However we are able to map the analyses to the specialties defined as high risk and low risk and model parameters are expressed as such.
There are two routes into hospital via a pre-admission clinic for all elective procedures via the emergency admissions ward for all emergency patients	There are many routes into hospital • via a pre-admission clinic for some elective procedures • directly into specialist ward for elective admissions • directly into specialist ward for emergency admissions • via the emergency admissions ward for all emergency admissions • by transfer from another hospital

NHS QIS HTA	Pathfinder
Screening test comprised of one nasal test per patients	Screening test comprised of one nasal test per patients and another indicative sites (devices or skin breaks) within certain specialties full body screen was continued [4]
Time frame for the model was 5 years	Pathfinder project was undertaken over one calendar year
Patients with a positive test may: • be colonised and subsequently acquire an MRSA infection during their hospital stay • be colonised and remain without infection • have an infection on admission to hospital • be a false positive where a laboratory test wrongly classifies a patient as positive when their true status is negative	Patients with a positive test may: • be colonised and subsequently acquire an MRSA infection during their hospital stay • be colonised and remain without infection • have an infection on admission to hospital • be a false positive where a laboratory test wrongly classifies a patient as positive when their true status is negative
Patients who were identified with an MRSA infection on admission are excluded from the model	Patients who have infection on admission are isolated where possible, treated for their infection and decolonised if appropriate and included in model
Elective patients are screened at pre-admission and admitted as known positive directly into isolation	Some elective patients are screened pre-admission and those found positive decolonised preadmission. Those known positive are isolated or cohorted on admission
Decolonisation included nose, skin and throat	Decolonisation included nose and skin and throat only when considered to be clinically appropriate [5]
Patient management was simplified to two options for patient management: • housed in a single bed isolation room • in a bed on an open ward	There are many options for patient management the following broad categories were used: • isolation in a single bed room with dedicated nursing staff (Classified as isolated) • isolation in a single bed room with no dedicated nursing staff • cohorting several patients in a geographically distinct location with dedicated nursing staff (Classified as cohorted) • cohorting several patients in a geographically distinct location without dedicated nursing staff (Classified as separated) • placement on a standard ward with no physical segregation from other patients (Classified as in bed on open ward)
Patients identified by a screen test as MRSA positive were placed in a single bed isolation room capacity permitting	Patients identified by a screen test as MRSA positive were placed in one of the areas described above

7.2 Modelling approach used within the NHS QIS HTA

Within the NHS QIS HTA [2] seven studies were included in the literature analysis for the model design. [6-12]. At the time of writing, these studies were not directly generalised to the population of NHSScotland and the MRSA incidence found there. These studies did not reach a consensus on the most cost and clinically effective screening strategy. Therefore a model was designed with pooled results taken from some studies and single parameters from others [2].

The objective of the NHS QIS HTA economic model [2] was "to inform recommendations to NHSScotland on the efficient use of MRSA Screening options by comparing strategies including the different combinations of clinical risk assessment and swab screening tests currently available in Scotland" and "to identify the level of isolation facilities required to reduce the prevalence of MRSA".

7.2.1 Description of the model

The model represents a single hospital and the community it serves. Full details of the Simile model™ and the real world representations of the model can be found on Simulistics website http://www.simulistics.com/projects/mrsa/index.htm.

The design of the NHS QIS HTA model was according to the Guidance for manufacturers on submission of evidence to health technology assessments 2002 [13].

The modelling approach is based on stock-and-flow modelling (commonly known as System Dynamics), in which a system is represented as a set of pools with flows into, out of and between them. In this case, the pools represent number of people.

In conventional System Dynamics, the stocks and flows represent the amount and rate-of-flow of some substance (e.g. water). These models generally involve values on a continuous scale (e.g. 10.357 litres), and are usually deterministic (you get the same result each time you run the same model). It is not appropriate to model small numbers of individuals in this way. Therefore, this model has been engineered so that all the flows are in terms of whole (integer) numbers. Consequently, the model used stochastic (probabilistic) methods to decide randomly whether the value of a flow will be zero, one, two or three individuals if the mean rate is (for example) 1.357. The main method used was to sample from a binomial distribution, to generate a number of individuals given a population size (n) and a probability (p) of some event happening.

The model tested a number of different combinations of microbiological test and screening strategies.

1. Do nothing - treat all admissions as uncolonised
2. Test all admissions to identify colonised individuals
3. Test admissions going for high-risk specialties - treat others as uncolonised
4. Risk assess all admissions (i.e., assess their risk of colonisation from their clinical history) and test those with a positive assessment. Treat others as uncolonised
5. Test all admissions going for high-risk specialties, risk assess others and test those with a positive assessment
6. Test all admissions, also risk assess them and treat those with positive assessment as colonised pending test results.

Each of these screening strategies was modelled using three types of different clinical tests described in the literature as techniques for testing MRSA colonisation. These tests were:

1. Screening agar
2. Chromogenic agar
3. Real-time Polymerase Chain Reaction (PCR)

A number of combinations of these laboratory tests are possible as patients can be screened at two points within their journey, at pre-admission clinic (elective admissions only) or on admission.

Table 7-2 Laboratory test combinations tested within the NHS QIS HTA model

Screening combination	Preadmission screening	On-admission screening	Code for Screening test combinations
1	Agar	Agar	AgAg
2	Agar	Chromogenic agar	AgChrom
3	Chromogenic agar	Chromogenic agar	ChromChrom
4	Chromogenic agar	PCR	ChromPCR

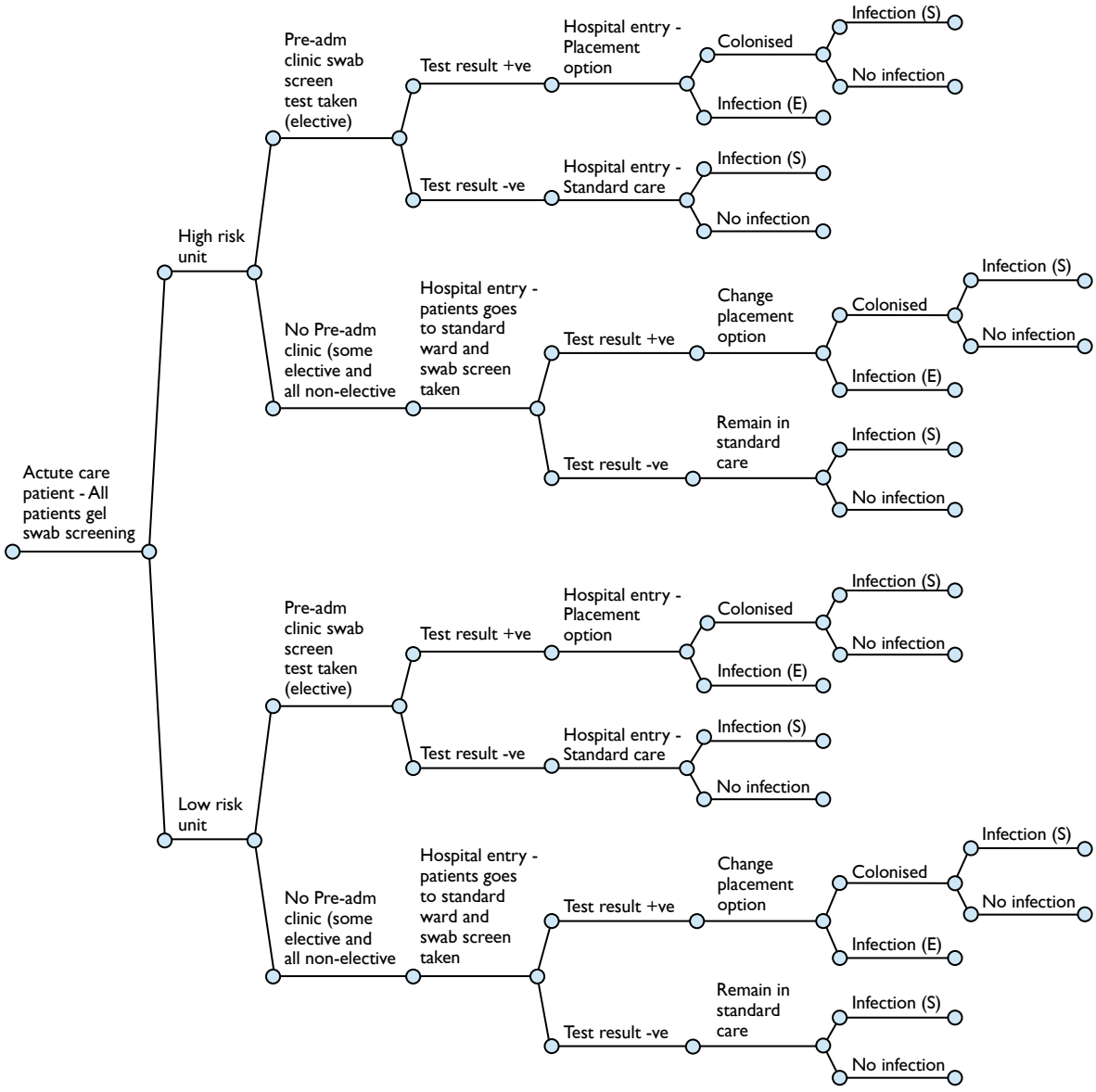
PCR was considered only for admission screen. The turn around requirement for pre-admission tests caused PCR to be excluded as it was the most expensive test.

Due to the uncertainty around many of the parameters (particularly colonisation and transmission rates) the usual best practice of adopting a societal perspective was not included. The societal perspective introduces further uncertainty to a model and therefore the evaluation of the various strategies was based on a cost consequence (i.e. the maximum effect on outcome compared and the minimum investment of funds).

The NHS QIS HTA model was based on the work by Cooper *et al* [1] which modelled a single hospital and community population pool to assess the impact of isolation policies on MRSA transmission. The NHS QIS HTA model represents the first attempt to model the effect of different screening strategies on the management of MRSA transmission within the acute hospital environment.

The recommendation from the NHS QIS HTA was that Strategy 2 (universal screening) was adopted along with the third screening combination which used chromogenic agar for both pre-admission and admission screen test as it was found to be the most clinically and cost effective test. Figure 7-1 shows a description of the NHS QIS HTA Strategy 2 patient pathway which was implemented within the Pathfinder Boards.

Figure 7-1: NHS QIS HTA 13-2 page 142 Description of the recommended Strategy 2 patient pathway: test all admissions



The Pathfinder project has been established using chromogenic agar for all microbiological screening tests for MRSA and all admissions are screened.

A number of limitations of the model have been identified both during the original development work and subsequently.

7.3 Task 2: To re-populate the model produced during the NHS QIS HTA using the parameters collected within the Pathfinder project

The Pathfinder project collected the parameters outlined within the NHS QIS HTA through an intensive data collection process. These parameters were input into the model used for the NHS QIS HTA. The parameters used in the re-population of the model and the findings are described within the results section of this report (see Section 10).

7.4 Task 3: To review the overall effect on the outcomes and compare the model output to the effect found within the Pathfinder Boards

The NHS QIS HTA model was developed and structured to reflect the assumptions described above and the data available from literature reviews and clinical opinion. The outcomes of the NHS QIS HTA model when re-run with Pathfinder data were not robust due largely to the fact that many of the assumptions built into the design of the model were found to be untrue and many of the parameters used to populate the model were significantly different from those used in the model.

7.5 Task 4: To alter the model using the knowledge gathered during the Pathfinder Project

A number of changes were made to the model based on the findings described within the assumptions sections of these results. These changes were undertaken by modellers at Simulistics who were contracted to make alterations to the model on behalf of HPS. This work was subsequently peer reviewed by a team of modellers working for the University of Abertay (see Section 15).

Table 7-3: List of changes made to model structure

Changes to model structure
Major changes are: - presence of pre-identification patients in general wards; - use of probabilistic turn-around time; - categorisation of pre-identification patients; - probabilistic length of stay in emergency receiving ward; - simplification of handling strategy; - first-in first-out operation of isolation rooms.
Minor changes to the model are: - explicit burn-in time; - addition of time-to-swab; - addition of compliance test; - having only one emergency ward; - change interpretation of length of stay.

7.6 Task 5: To consider the implications and cost predictions of the model compared to the findings of the Pathfinder project and consider the implications for MRSA screening in NHSScotland

The cost predictions for universal screening have been based on a re-worked ready reckoner for all of Scotland. This includes the prevalence of each specialty and the number of admissions to each specialty. This is more specific than the model which assumes the same prevalence in each specialty which is not very useful when trying to plan resources at an implementation level within an NHS board.

In contrast to the NHS QIS HTA the staff costs and consumable costs have been separated in order to assist division of funds to laboratories and pharmacies in a practical way. For full details on these calculations please refer to the organisational issues section of the report [14].

8 Assumptions

A number of assumptions were made in the development of the model during the development of the NHS QIS HTA. A key finding was that the literature on MRSA screening was limited and high quality studies were very scarce. The model was designed based on the best quality studies published by 2005 when the NHS QIS HTA literature search strategies were run. The design of the Pathfinder study was to implement Strategy 2 using chromogenic agar for pre-admission and admission screens, and collect data on as many parameters as possible in the model but also to collect information on issues arising from this implementations to test if the assumptions made held true. These are outlined below in terms of assumptions that were not possible to test within the implementation study design used within the Pathfinder project (Table 8-1) and those assumptions which were shown not to hold true within the implementation study design used within the Pathfinder project (Table 10-1).

Table 8-1: Assumptions made in the development of the NHS QIS HTA model Strategy 2 which have not been addressed during the Pathfinder Project.

NHS QIS HTA	Comment
Colonisation occurs only in hospital, i.e. there is no transmission within the community pool	Not possible to assess with the programme. This would require a separate research study
Loss of positive colonisation status can occur spontaneously in the community or in hospital and does so at the same rate in both settings	Not possible to assess with the programme. This would require a separate research study
Recently discharged patients experience a high risk of re-admission back into hospital, which falls over time to a constant lower risk level	Although many admissions were re-admitted within the study period, it was not possible to address this issue within the Pathfinder project
The risk of colonisation experienced by a non-colonised patient is proportional to the number of non-isolated carriers on the same ward	Although a clear variation was shown in prevalence from specialty this study did not allow any inference to be made about MRSA colonisation acquired during hospital stay. This will be address within special studies.
Change in MRSA colonisation status occur at a constant rate	A direct relationship has been shown between prevalence and repeat admission (Volume 1 [3]), however this study does not allow any estimate of the change in MRSA colonisation status over time.
MRSA colonisation is constant within the hospital i.e. There is a steady state of patients who are colonised within hospital and those who are decolonised	This will be investigated with the Special studies undertaking both admission and discharge testing, planned for initiation in January 2010
Patients in single bed isolation rooms transmit to patients out with the isolation room at a lower rate than patients in the open ward.	Not possible to assess with the programme. This would require a separate research study
MRSA colonised and non colonised patients are discharged back into the community at a fixed rate independent of colonisation or isolation status	Not possible to assess with the programme. This would require a separate research study

NHS QIS HTA	Comment
The size of the community pool remains constant	There are some small fluctuations in the size of the community pool over time [16]. This assumption is found to be true.
Costs attributed to MRSA false positives were identical to the cost attributable to true positive patients	All positives within the Pathfinder project were treated the same way, this assumption was found to be true.
Transmission only occurred within a ward and not between	Not possible to assess with the programme. This would require a separate research study
It has been assumed for the purposes of the modeling described here, that one strategy would be adopted and maintained for a five-year period	This will be a policy decision for SGHD
For the purposes of the economic model, it was assumed that following identification of colonised or infected patients, measures can be implemented to isolate them which would result in a reduction of the transmission rate of MRSA to zero. How this could be achieved practically in the hospital setting is unclear. From the results of their systematic review, Cooper *et al.*[1] concluded that, despite the shortcomings of the published literature, there is evidence that isolation can reduce MRSA transmission	The Pathfinder boards although having more than three single rooms per ward on average did not have sufficient single rooms to allow all admissions to be isolated. These rooms were required for patients with a range of different conditions. (48% of positive admissions were isolated or cohorted) (Table 9-17). Although it is clear that all MRSA positive admissions have not be isolated and therefore it is unlikely that the transmission rate has been reduced to zero, no estimate of transmission rate is possible within this study. (This will be investigated within a special study planned for initiation in January 2010).
Within the hospital, specialist wards are grouped into two categories, high and low-risk specialty wards. For the tertiary referral hospital, two out of the 15 high-risk specialty wards and three out of the 19 low-risk specialty wards were assumed to be occupied by over 65s only.	The re-worked model did not attempt to emulate a specific hospital in the pathfinder study but a theoretical generic hospital which represents NHS Scotland's hospitals. This was used in the re-working
Clinical risk assessment was assumed to be instantaneous and to partition patients as 'likely to be carriers' and 'not likely to be carriers'	This will be investigated with the Special studies undertaking both admission and discharge testing, planned for initiation in January 2010
The assessment applies an MRSA screening model to the hospital setting. The simplified nature of a model means that many of the interactions observed at ward level are not taken into account. The only driver of MRSA prevalence explored was colonisation pressure, which was assumed to be fixed. All other factors associated with transmission of infection, known and unknown, were assumed to be comparable across the hospital setting and to be independent of colonisation pressure.	Not possible to assess with the programme. This would require a separate research study
The model assumed fixed transmission rates but did not model the transmission process or consider vectors such as transient colonisation of staff and visitors and subsequent transmission, environmental factors and bed spacing.	Not possible to assess with the programme. This would require a separate research study

NHS QIS HTA	Comment
It has also been assumed that patients are equally likely to become colonised or infected throughout their stay in hospital whereas it is more probable that this will vary depending on the level of intervention they experience at different points in time, for example before versus after an operation. The effect of factors such as these on the outcomes of adopting a systematic approach to screening for MRSA would require to be tested empirically within a hospital system	Not possible to assess with the programme. This would require a separate research study
A key assumption of the model is that isolation reduces MRSA transmission to zero.	Not possible to assess with the programme. This would require a separate research study
It has been assumed that there are three single rooms available per ward for isolation of patients found to be colonised with MRSA.	The pathfinder project only collected data on whether a positive patient was able to be isolated not on the overall use of isolation rooms. On average this was true in that single rooms were present within the design of the ward, however these were used for all admissions not just MRSA isolation.
MRSA patients become infected at a fixed rate and where possible, infected patients are isolated immediately. The only consequence of infection include in the model was increased length of stay. Mortality, morbidity, and antibiotic use following MRSA infection were not considered.	This was not addressed in the Pathfinder study objectives
The model assumed that while patients are resident in isolation rooms, healthcare staff implement contact precautions in addition to standard nursing procedures. When patients were placed in a single-bed isolation room, it was assumed that all healthcare staff would implement standard infection control polices and additionally adhere to contact precautions as described by Siegel *et al.*[16]	This was the policy within the boards. Two audits were conducted during the Pathfinder to examine compliance with this policy [14].
This economic model assumed 12 patient contacts per day by healthcare staff, with three minutes per patient contact was needed to ensure compliance with contact precautions [2].	Not possible to assess with the programme. This would require research study
Contact precautions were assumed to be additional to the normal level of care provided, and thus the cost was additional to the average daily cost of hospital stay.	The assumption should be best practice.
For the purposes of modeling, the hospital was assumed to be operating at full capacity, i.e. in the absence of MRSA infection, the discharge and admission rates were assumed to balance.	Although the Pathfinder project did not attempt to measure the capacity of the hospital, [15] the hospital admissions and discharges did not change as a result of the Pathfinder Project. There were very few deferred admissions (Page 51). It is assumed that the hospital was working at full capacity.

NHS QIS HTA	Comment
Decolonisation of MRSA-positive patients has been recommended by recent guidelines [5]. A 53% successful decolonisation estimate was assumed for the economic model, based on the study of Rohr *et al.* [17] where outcome was assessed one to two days following five to seven day mupirocin treatment.	6.9% of admissions were successfully decolonised during their stay. In order to investigate this fully a follow up research study post discharge would be required.
It was assumed that pure isolates for all MRSA-positive samples are sent to the MRSA Reference Laboratory.	This was true for the duration of the Pathfinder Programme as the reference Laboratory were provided with additional funds to undertake these tests. On completion of the Pathfinder project the reference laboratory referral strategy will return to the current Snapshot programme and policy decisions will be required around the reference laboratory requirements for national rollout.

9 Results to address Aim 2

9.1.1 *Aim 2 Objective 1: To identify the proportion of elective admissions who attend pre-assessment clinics and the proportion that were screened and the reasons for not screening*

Approximately one quarter of elective admissions attended pre-admission clinics. Of those who were attended pre-admission clinics 97.8% (6,305 /6,448) were screened. These figures varied by NHS Board and were dependant on the extent to which pre-admission clinics were held in each hospital.

In Grampian fewer elective admissions attended a pre-admission clinic however where a patient attended a pre-admission clinic 98.8% (3,685/3,797) were screened. The highest total proportion of elective admissions screened pre-admission was in Ayrshire and Arran at 47.1% (3,685/7,823). Although there were differences in the proportions of elective admissions screened at different pathfinder boards the small numbers and proportion screening positive did not vary significantly between sites (2.0 – 2.2%).

Table 9-1 shows the number of elective admissions who were screened by individual pathfinder sites and the number and percentage of elective admissions screened by specialty of admission. There were 135 admissions which screened positive at pre-admission clinics, five of whom were subsequently admitted as emergency patients and have been excluded from Table 9-1.

Table 9-1: Number and percentage of elective patient admissions identified as MRSA positive by screen at pre-assessment clinic, by pathfinder board, N=25,369

Pathfinder Board	Elective Admissions	Elective Admissions Attending Pre admission	Elective Admissions Screened at Pre-admission Clinics		Elective Admissions Screened Positive of those screened for MRSA at Pre-admission Clinics	
	N	n	n	%	n	%
Ayrshire and Arran	7,823	3,797	3,685	47.1	74	2.0
Grampian	16,910	2,374	2,346	13.9	50	2.1
Western Isles	636	277	274	43.1	6	2.2
Total	**25,369**	**6,448**	**6,305**	**24.9**	**130**	**2.1**

Multivariate logistic regression, clustered by patient admissions, was carried out to investigate the best predictors of being screened at pre-admission clinics among the 6,448 elective admissions attending a pre-admission clinic. The outcome variable was "screened at pre-admission clinic" (Table 9-2).

Variables included in the model were age at admission, gender, type of admission (elective or emergency), frequency of admission in the study year, hospital and specialty admitted to and where the patient was admitted from (home or not). Interactions with age group, gender and type of admission were tested and found to be not significant. The significant variables are displayed in Table 9-2. In order of importance the variables that independently best predicted "screened at pre-admission clinic" were hospital and specialty. The model is based on elective admissions only and therefore only the specialties which were identified as treating elective admission are included.

From Table 9-2 it can be seen that the odds of being screened at pre-admission clinic were 3.5 times higher for Woodend Hospital than Ayr Hospital (baseline). This is as expected as the orthopaedics unit in Woodend Hospital was included in the study and therefore admissions were more likely to attend a pre-admission clinic. For Western Isles Hospital the odds were 1.7 times higher than Ayr Hospital. (Odds for being screened at pre-assessment clinic were lower admitted to the following specialties: oncology (0.13), medicine (0.30) and orthopaedics (0.42) than to the admission specialty Surgery (baseline).

Table 9-2: Results of multivariable clustered logistic regression analyses of being screened at pre-admission among the N= 6,448 admissions who were screened during the study period August 2008 – July 2009

Variable	Subgroup	Regression Coefficient (standard error)		P Value	Odds Ratio (95% CI)
Hospital	Ayr Hospital (baseline)	0	-	-	1
	Aberdeen Royal Infirmary	-0.483	0.320	0.131	0.617 (0.329 - 1.156)
	Woodend	1.250	0.400	0.002	3.489 (1.592 - 7.643)
	Crosshouse	-1.329	0.234	<0.0001	0.265 (0.167 - 0.419)
	Western Isles	0.512	0.739	0.488	1.669 (0.392 - 7.109)
	Uist and Barra	-0.785	1.206	0.515	0.456 (0.043 - 4.849)
Speciality	Surgery (baseline)	0	-	-	1
	Medicine	-1.211	0.875	0.167	0.298 (0.054 - 1.657)
	Oncology	-2.007	0.673	0.003	0.134 (0.036 - 0.502)
	Orthopaedic	-0.863	0.215	<0.0001	0.422 (0.277 - 0.642)
	constant	4.573	0.228	-	
Log Likelihood: -642.406		Degrees of Freedom: 9			AIC: 1363.738

Table 9-3 shows the number of admissions, percent of admissions, the number of pre-admission screens and percentage of pre-admission screens among those electives attending a pre-admission clinic, for the variables found to be important in the regression analyses. This table shows that for all hospitals and specialties more than 91% of the admissions who attended a pre-admission clinic were screened there. In areas where a lower percentage of the total attendees of pre-admission clinics were screened this may be due to the fact that the admissions who have been admitted during the study period may have attended pre-admission clinic before the study began and care should be taken in interpreting these data.

Table 9-3: Number and percentage of admissions, and number and percentage screened among the N= 6,448 elective admissions attending pre-admission during the study period August 2008 – July 2009; by hospital of admission and specialty of admission

Variable	Subgroup	Elective Admissions Attending Pre-admission		Screened Elective Admissions Attending Pre-admission	
		N	%	n	%
Hospital	Aberdeen Royal Infirmary	1,107	17.17	1,088	98.3
	Woodend	1,267	19.65	1,258	99.3
	Ayr	1,953	30.29	1,925	98.6
	Crosshouse	1,844	28.60	1,760	95.4
	Western Isles	245	3.80	243	99.2
	Uist and Barra	32	0.50	31	96.9
Specialty	Accident and Emergency	*	*	*	*
	Cardiology	7	0.11	7	100.0
	Care of the elderly	*	*	*	*
	Intensive Care/HDU	*	*	*	*
	Medicine	28	0.43	26	92.9
	Oncology	36	0.56	33	91.7
	Orthopaedic	2,118	32.85	2,072	97.8
	Renal	*	*	*	*
	Surgery	4,254	65.97	4,162	97.8

*Indicates values that have been suppressed due to the potential risk of disclosure

9.1.2 Aim 2 Objective 2: To identify the proportion of emergency admissions and specialty transfer (between hospitals) who were screened on admission.

Of all emergency admissions 85.3% (47,805/56,069) were screened. Of those screened 4.5% screened positive this is significantly greater than the percentage of all elective admissions who are found to be MRSA colonised.

Multivariable logistic regression, clustered by patient admissions, was carried out to investigate the proportion screened among emergency admissions and specialty transfer (between hospitals). There were 57,121 admissions included in the regression.

Variables included in the model were age at admission, gender, type of admission (elective or emergency), frequency of admission in the study year, hospital and specialty admitted to and where the patient was admitted from (home or not). Interactions with age group, gender and type of admission were tested and found to be not significant.

The significant variables are displayed in Table 9-4. In order of importance the variables that independently best predicted screened on admission were length of stay, month of admission, specialty and hospital admitted to and where the patient was admitted from (home or not). From the table it can be seen that the odds of being screened among those that stayed over eight nights were 3.9 times higher than those that stayed only one night while the odds of those staying two to three nights and four to seven nights were, respectively, 1.8 and 2.4 times higher than the baseline category of one night.

Admissions during the last quarter of the study (March-July 2009) had 2.8 times higher odds of being screened than those during the first quarter of the project (August-October 2008). The odds of being screened therefore increased over time.

Admission specialties: intensive care, medicine, cardiology and accident and emergency have approximately twice the odds of being screened on admission to hospital than the baseline category Surgery. The odds of those screening among those admitted from places other than home (such as care homes and other hospitals) were lower than those who were admitted from home.

Table 9-4: Results of multivariable clustered logistic regression analyses of being screened among the N=57,121 emergency admissions, and specialty transfer between hospitals, during the study period August 2008 – July 2009

Variable	Subgroup	Regression Coefficient (standard error)		P Value	Odds Ratio (95% CI)
Month of Admission	Admission Aug-Oct (baseline)	0	-	-	1
	Nov-Jan	0.690	0.033	<0.0001	1.993 (1.868 - 2.126)
	Feb-Apr	0.959	0.035	<0.0001	2.608 (2.435 - 2.793)
	May-Jul	1.034	0.035	<0.0001	2.811 (2.624 - 3.013)
Hospital	Ayr Hospital (baseline)	0	-	-	1
	Aberdeen Royal Infirmary	-0.822	0.041	<0.0001	0.440 (0.406 - 0.476)
	Woodend	-3.128	0.245	<0.0001	0.044 (0.027 - 0.071)
	Crosshouse	-0.550	0.045	<0.0001	0.577 (0.528 - 0.631)
	Western Isles	0.354	0.112	0.002	1.425 (1.145 - 1.774)
	Uist and Barra	0.921	0.339	0.007	2.513 (1.292 - 4.886)
Admitted from	Admitted from home (baseline)	0	-	-	1
	Not admitted from home	-0.350	0.041	<0.0001	0.705 (0.651 - 0.763)
Speciality	Surgery (baseline)	0	-	-	1
	Accident and Emergency	0.670	0.056	<0.0001	1.954 (1.752 - 2.181)
	Cardiology	0.733	0.054	<0.0001	2.081 (1.870 - 2.315)
	Care of the Elderly	0.173	0.094	0.066	1.189 (0.988 - 1.429)
	ICU	0.768	0.115	<0.0001	2.156 (1.722 - 2.700)
	Medicine	0.780	0.031	<0.0001	2.182 (2.055 - 2.317)
	Oncology	-0.575	0.078	<0.0001	0.563 (0.483 - 0.656)
	Orthopaedic	0.576	0.049	<0.0001	1.778 (1.615 - 1.958)
	Renal	0.355	0.076	<0.0001	1.427 (1.230 - 1.655)
Length of Stay	LOS 1 night (baseline)	0	-	-	1
	2-3 nights	0.615	0.033	<0.0001	1.850 (1.734 - 1.973)
	4-7 nights	0.869	0.035	<0.0001	2.383 (2.224 - 2.555)
	8+ nights	1.359	0.037	<0.0001	3.891 (3.616 - 4.187)
	constant	0.593	0.046	-	
Log Likelihood: -21515.620		Degrees of Freedom: 21			AIC: 43073.250

Table 9-5 shows the number of admissions and the number and percentage screened among each group for the variables found to be important in the regression analyses.

Table 9-5: Number and percentage of admissions, and number and percentage screened among the N=57,121 emergency admissions, and specialty transfer between hospitals during the study period August 2008 – July 2009; by hospital of admission and specialty of admission

Variable	Subgroup	Emergency Admissions and Hospital Transfers		Screened Emergency Admissions and Hospital Transfers	
		N	%	n	%
Month of Admission	Aug-Oct	11,771	20.6	8,754	74.4
	Nov-Jan	15,446	27.0	13,269	85.9
	Feb-Apr	14,614	25.6	12,905	88.3
	Mar-Jul	15,290	26.8	13,563	88.7
Hospital	Aberdeen Royal Infirmary	27,863	48.8	22,549	80.9
	Woodend	98	0.2	36	36.7
	Ayr Hospital	11,364	19.9	10,367	91.2
	Crosshouse	15,588	27.3	13,447	86.3
	Western Isles	1,858	3.3	1,751	94.2
	Uist and Barra	350	0.6	341	97.4
Admitted from	Admitted from home	51,685	90.5	44,143	85.4
	Not admitted from home	5,436	9.5	4,348	80.0
Specialty	Accident and Emergency	3,138	5.5	2,496	79.5
	Cardiology	4,223	7.4	3,737	88.5
	Care of the elderly	1,465	2.6	1,312	89.6
	Intensive Care/HDU	1,069	1.9	977	91.4
	Medicine	25,981	45.5	23,042	88.7
	Oncology	892	1.6	594	66.6
	Orthopaedic	4,912	8.6	4,182	85.1
	Renal	2,222	3.9	1,928	86.8
	Surgery	13,169	23.1	10,178	77.3
	Not known	50	0.1	45	90.0
Length of Stay	1 night	14,461	25.3	11,020	76.2
	2-3 nights	13,554	23.7	11,400	84.1
	4-7 nights	12,999	22.8	11,394	87.7
	8+ nights	15,534	27.2	14,280	91.9
	Not known	573	1.0	397	69.3

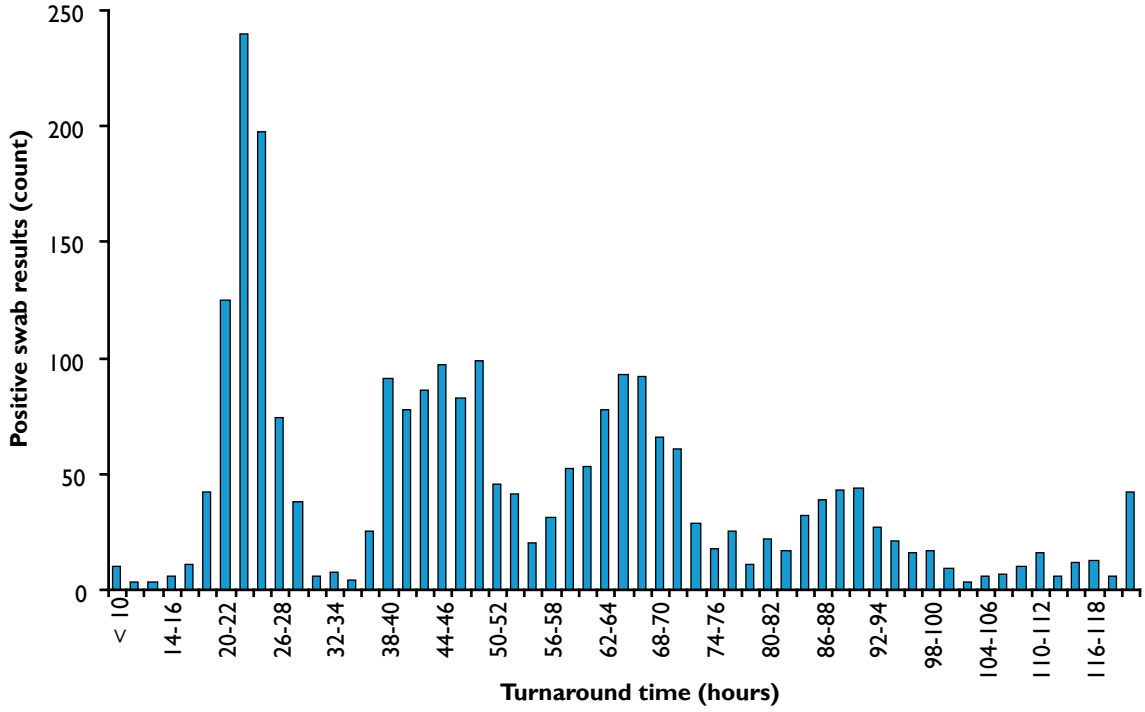
9.1.3 Aim 2 Objective 3: To monitor the turnaround time (TAT) for reporting from sample collection to reporting by laboratories and where the potential delays are.

Turnaround time was calculated as the time the screening sample was taken until the time the clinical unit was informed of the results by the laboratory.

There were 62, 694 records where turnaround time was recorded. Figure 9-1 shows the turnaround time for negative swabs (N=60,181). Figure 9-2 shows turnaround time for positive swabs (N=2,513). The distribution of turn around times reflects laboratory operation and time of admission; this distribution is mirrored in both positive and negative test results and throughout each pathfinder board.

Positive samples N= 2,513 (4%) had at 48 hours a longer median turnaround time than those of negative samples (IQR: 25 – 68).

Figure 9-1:Turnaround time for positive result swabs N= 2,513



Negative samples N=60,181 (96%) had a median sample turnaround time of 28 hours (IQR: 24 – 43). Figure 9-2 shows the turnaround times for negative test results for each pathfinder site.

Figure 9-2:Turnaround time for negative swabs N= 60,181

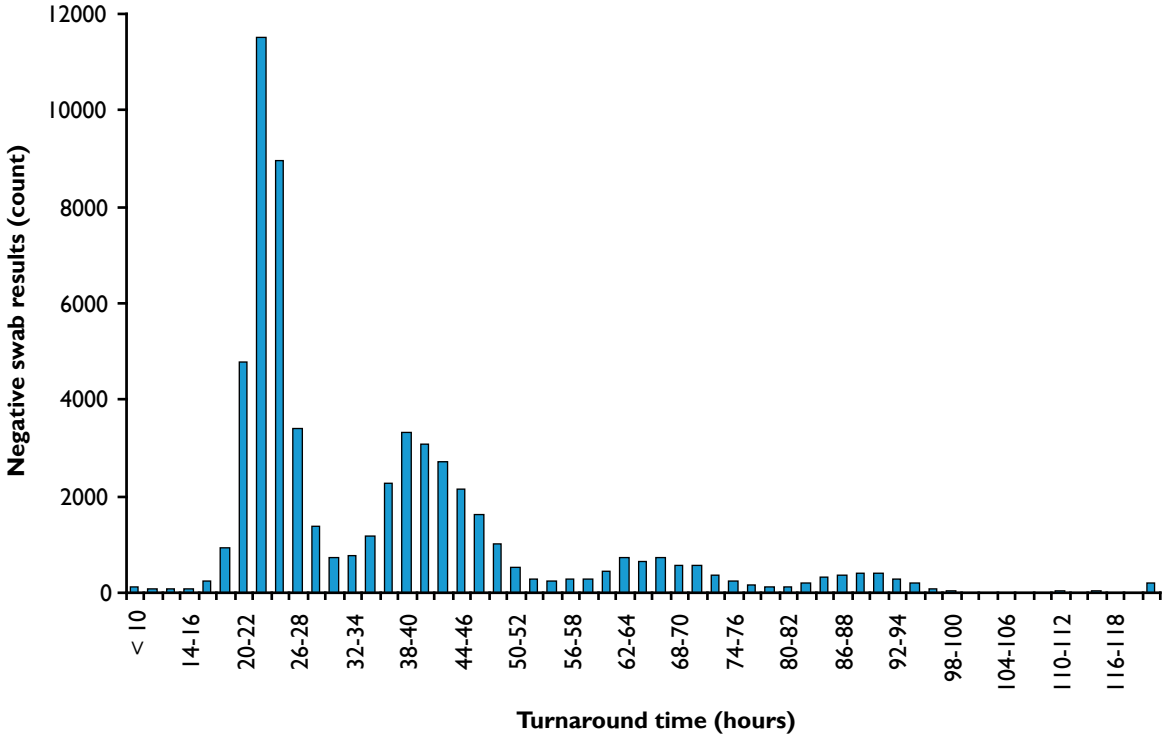


Figure 9-3 shows the turnaround times for positive test results for each pathfinder site. The median turnaround time varied by pathfinder site for both negative and positive results.

Figure 9-3:Turnaround time for positive results by Pathfinder Board N= 2,513

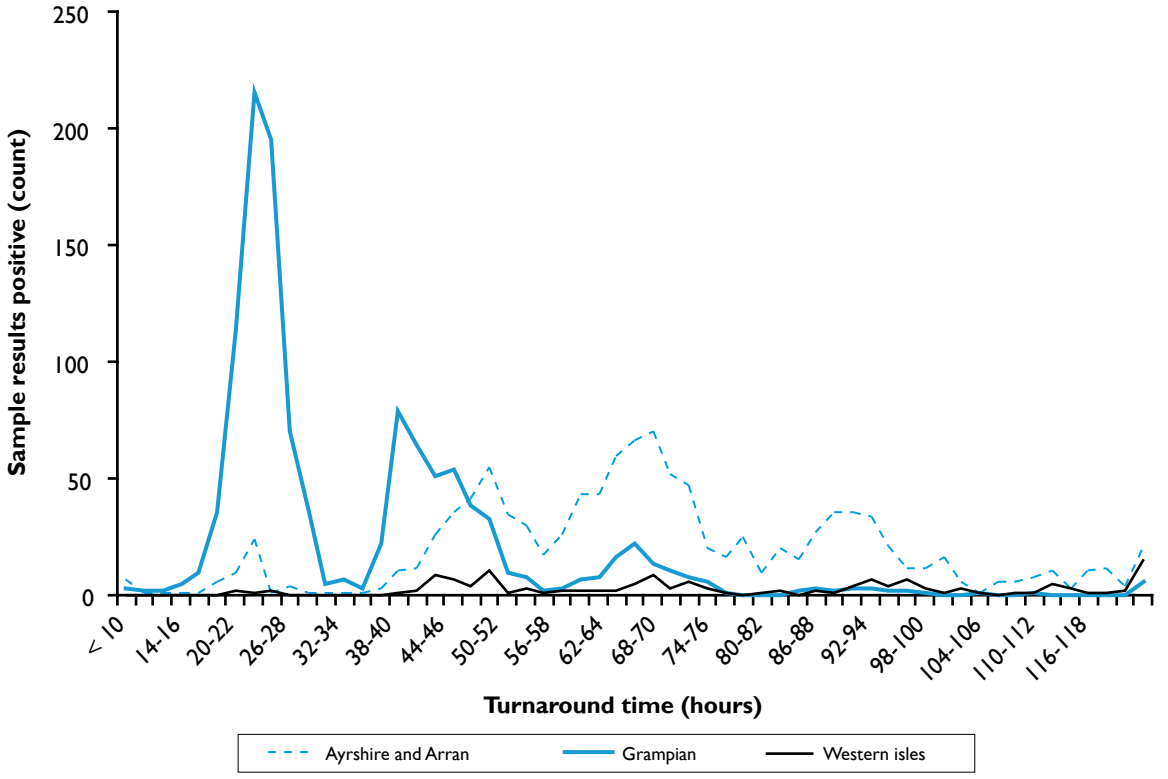


Figure 9-4 shows the turnaround times for negative test results for each pathfinder site.

Figure 9-4:Turnaround time for negative samples by Pathfinder Board N=60,181

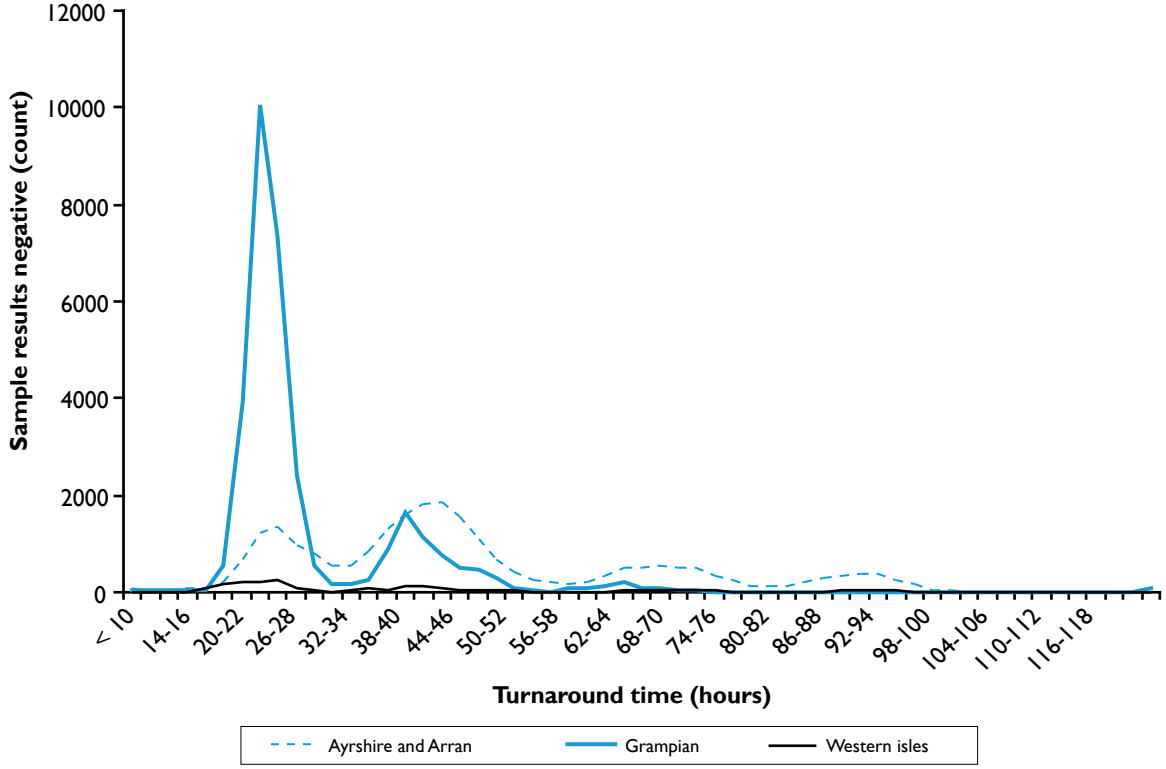


Table 9-6 shows the turnaround time for positive and negative samples from each of the pathfinder boards. For positive samples the longest median turnaround time was in Western Isles 70.5 hours (IQR 49 – 97) and the shortest time was in Grampian 26.0 hours (IQR 23 – 42.5). For negative samples the longest median turnaround time was in Ayrshire and Arran at 42 hours (IQR 32.5 -60) and the shortest time was again in Grampian at 24 hours (23 – 28). For the total number of pathfinder screening samples, 50.1% of positive results were reported within 48 hours. In Ayrshire and Arran this figure was 16.8%, in Grampian 85.3% and in Western Isles 19.4%.

Table 9-6: Median and percentiles of turn around time (TAT) for time admission screen taken to availability of result by pathfinder board N=62,694.

Pathfinder Board	TAT of Positive Results (hours)				TAT of Negative Results (hours)			
	N	Median	25th Percentile	75th Percentile	N	Median	25th Percentile	75th Percentile
Ayrshire and Arran	1,149	66	52	84.0	25,187	42	33	60
Grampian	1,220	26	23	42.5	32,758	24	23	28
Western Isles	144	70.5	48	97	2,236	35	23	49
Total	**2,513**	**48**	**25.4**	**68**	**60,181**	**28**	**24**	**43**

Multivariable regression, clustered by patient admissions, was carried out to investigate the turn around time of all admission screens. Turn around times were known for 62,694 of the 69,445 admission screens (90.3%).

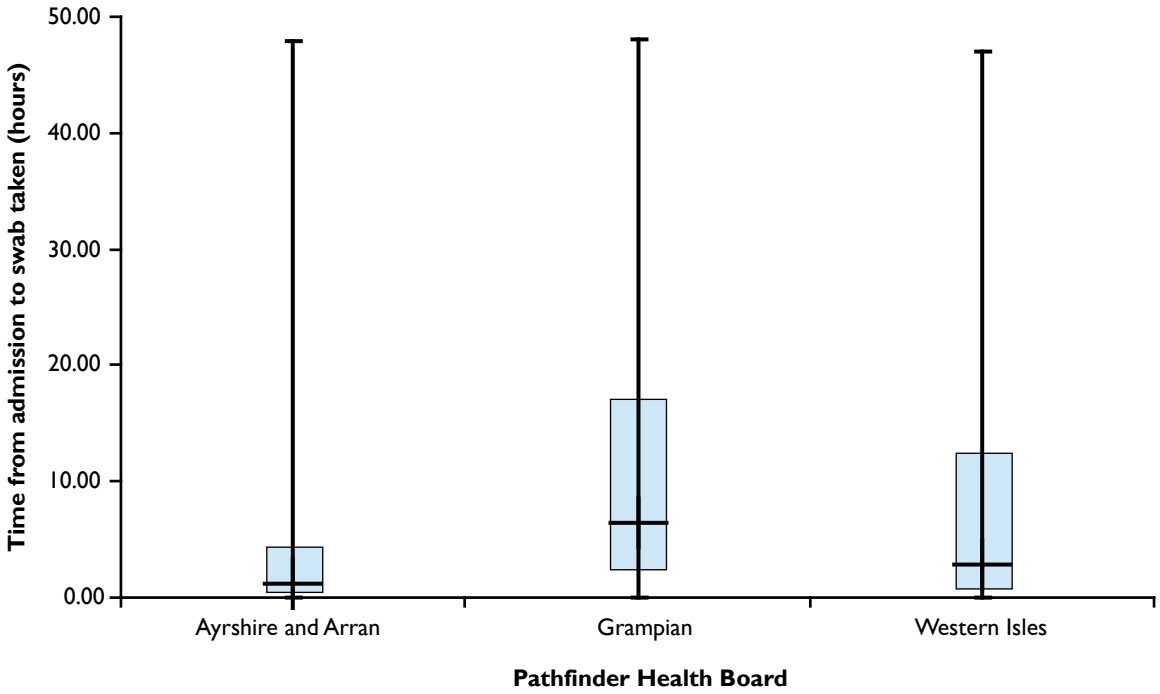
Variables included in the model were type of admission (elective or emergency), hospital and specialty admitted to, screening result on admission, time of day and day of week that the swab was taken. Many of the variables were found to be independently associated with turn around time. In order of importance they were type of admission, hospital, time swab was taken, day swab was taken, and the result of the admission screen (Table 9-7).

Table 9-7: Results of multivariable clustered linear regression analyses of time (in log hours) from swab taken to result returned to ward among the N=62,694 admissions for whom this was known, during the study period August 2008-July 2009

Variable	Subgroup	Regression Coefficient (standard error)		P Value	Ratio (95% CI)
Hospital	Ayr Hospital (baseline)	0	-	-	1
	Aberdeen Royal Infirmary	-0.379	0.004	<0.0001	0.684 (0.679 , 0.690)
	Woodend	-0.374	0.007	<0.0001	0.688 (0.678 , 0.697)
	Crosshouse	0.033	0.005	<0.0001	1.034 (1.024 , 1.044)
	Western Isles	-0.178	0.011	<0.0001	0.837 (0.820 , 0.854)
	Uist and Barra	0.248	0.022	<0.0001	1.282 (1.227 , 1.339)
Time Swab Taken	Swab taken 00-8.59 (baseline)	0	-	-	1
	9:00-16:59	-0.057	0.005	<0.0001	0.944 (0.935 , 0.954)
	17:00-23:59	0.147	0.005	<0.0001	1.158 (1.146 , 1.170)
Type of Admission	Elective (baseline)	0	-	-	1
	Emergency	0.032	0.003	<0.0001	1.032 (1.025 , 1.039)
Day Swab Taken	Swabbed Sunday (baseline)	0	-	-	1
	Monday	-0.100	0.005	<0.0001	0.905 (0.897 , 0.913)
	Tuesday	-0.100	0.004	<0.0001	0.905 (0.897 , 0.912)
	Wednesday	-0.093	0.005	<0.0001	0.912 (0.903 , 0.920)
	Thursday	0.051	0.006	<0.0001	1.053 (1.041 , 1.065)
	Friday	0.233	0.006	<0.0001	1.262 (1.248 , 1.277)
	Saturday	0.260	0.006	<0.0001	1.297 (1.282 , 1.311)
Screen Positive	Screen - (baseline)	0	-	-	1
	Screen positive	0.283	0.009	<0.0001	1.327 (1.303 , 1.351)
	constant	3.630	0.009	-	
Log Likelihood: -21380.17		Degrees of Freedom: 16			AIC: 42792.35

The time from admission to sample being taken can not be ignored in this analysis as this affects the total time until MRSA status is confirmed by the laboratory. The median time for admission swabs to be taken ranged from one hours in Ayrshire and Arran, three hours in the Western Isles and six hours within Grampian. The box plot shown in Figure 9-5 describes the median time from admission to swab taken. The timing for Uist and Barra Hospital include transfer to laboratory in Western Isles Hospital. The overall median time from admission to swab taken within the Pathfinder study was four hours.

Figure 9-5: Box and whisker plot showing the time from admission to swab being taken by Pathfinder Board. Ayrshire and Arran N = 17,842, Grampian N = 29,500, Western Isles N = 2,181 and Total N = 49,523



9.1.4 *Aim 2 Objective 4: To identify the proportion of admissions with a positive MRSA screen identified at a pre-assessment clinic who were not subsequently admitted as planned.*

Fifteen patient admissions screened at a pre-admission clinic were recorded as having their admission deferred. Fourteen of those admissions were recorded as having their admission deferred due to MRSA colonisation, this equates to 10.4% of all patient admissions screening positive at pre-admission clinics.

9.1.5 Aim 2 Objective 5: To identify the proportion of admissions screened for MRSA who were admitted to high-risk and low-risk specialty wards

A high risk specialty according to the literature is defined as, a clinical area where there is a higher risk of developing an MRSA infection. The total number of admissions who had a specialty recorded was 81,388. Of these, the total number of admissions to high risk specialties were 50,000 (61.4%) compared to 31,388 (38.6%) low risk admissions (Table 9-8). Admissions who were screened at pre-admission clinics were more likely to be admitted to high risk specialties than low risk specialties with 5,888/6,411 (91.8%) of those screened admitted to high risk specialties compared with 523/6,411 (8.2%) to low risk specialties. Conversely a lower percentage of admissions being admitted to high risk specialties were screened on admission 73.1% (36,539/50,000) compared to those being admitted to a low risk specialty 84.3% (26,450/31,388).

Table 9-8: Number and percentage of admissions by location of screen taken and high risk or low risk specialty. N=81,388 (Only admissions with specialty of admission are included within these analyses)

Screen taken	Total	Low risk		High risk	
	N	n	%	n	%
Pre-admission clinic screen	6,411	523	8.2	5,888	91.8
Admission screen only	62,989	26,450	42.0	36,539	58.0
Not screened	11,988	4,415	36.8	7,573	63.2
Total	**81,388**	**31,388**	**38.6**	**50,000**	**61.4**

Highest uptake of screening was achieved in smaller and more specialised units such as Intensive Care Units (ICU), Coronary Care Units (CCU) and High Dependency Units (HDU) with lower screening rates achieved in low risk units with a high turnover of patients such as oral surgery, Ear Nose and Throat (ENT) and ophthalmology. General medicine with the highest proportion of admissions, achieved one of the highest screening uptake at 90.2%.

There was considerable variation in the proportion of admissions found to be both colonised with MRSA and presenting with MRSA infection during their hospital stay. Within the group of specialties categorised as high risk 2.8% of admissions screened positive for MRSA colonisation and 0.2% were recorded as having MRSA infection. Within the group of specialties categorised as low risk 4.2% of admissions screened positive for MRSA colonisation and 0.2% were recorded as having MRSA infection (Table 9-10). Within the pathfinder study no difference in the proportion of admissions with infection was seen between high and low risk specialties. Table 9-9 shows the burden, infection and colonisation within high risk specialties. The highest burden was found in renal and vascular surgery, the highest proportion of infections was found in anaesthesia, cardiac surgery and vascular surgery and the highest proportion of positive screens were found in high dependency, intensive care and vascular surgery.

Table 9-9: Number and percentage of all admissions MRSA positive on admission to hospital, by high risk specialty during the study period August 2008 – July 2009, N=50,000

Admission Specialty	Total Admissions		Burden of All MRSA Positive		Admissions with MRSA Infections During Stay		Screened Positive Admissions		95% CI for Screened Positive	
High Risk	N	%	n	%	n	%	n	%	%	%
Anaesthesia / ICU	369	0.7	25	6.8	7	1.9	17	4.6	1.09	6.75
Cardiac surgery	623	1.2	21	3.4	8	1.3	11	1.8	0.64	2.89
Cardiology	4,376	8.8	317	7.2	12	0.3	138	3.2	2.57	3.74
Coronary care unit	346	0.7	21	6.1	*	*	7	2.0	0.54	3.51
Gastroenterology	4,026	8.1	445	11.1	8	0.2	192	4.8	4.06	5.48
General surgery (excluding vascular)	12,515	25.0	713	5.7	27	0.2	287	2.3	1.99	2.60
Gynaecology	3,445	6.9	71	2.1	*	*	42	1.2	0.85	1.59
Haematology	771	1.5	50	6.5	*	*	13	1.7	0.65	2.72
High dependency unit	717	1.4	85	11.9	*	*	41	5.7	3.91	7.53
Max fax	851	1.7	36	4.2	*	*	15	1.8	0.77	2.75
Medical oncology	779	1.6	41	5.3	*	*	14	1.8	0.76	2.83
Neurosurgery	905	1.8	44	4.9	*	*	20	2.2	1.17	3.25
Oncology	612	1.2	33	5.4	*	*	15	2.5	1.06	3.84
Ophthalmology	920	1.8	39	4.2	*	*	16	1.7	0.89	2.59
Oral surgery and medicine	39	0.1	*	*	*	*	*	*	*	*
Orthopaedics elective	4,581	9.2	156	3.4	*	*	66	1.4	1.09	1.79
Orthopaedics trauma	4,813	9.6	287	6.0	13	0.3	154	3.2	2.70	3.70
Plastic surgery and burns	777	1.6	33	4.2	*	*	11	1.4	0.58	2.25
Nephrology/ Renal	2,471	5	309	12.5	8	0.3	100	4.0	3.20	4.90
Thoracic surgery	308	0.6	16	5.2	*	*	6	1.9	0.40	3.50
Urology	4,336	8.7	344	7.9	10	0.2	170	3.9	3.23	4.61
Vascular surgery	1,420	2.8	204	14.4	14	1.0	68	4.8	3.62	5.96
Total	**50,000**	**100.0**	**3,290**	**6.6**	**121**	**0.2**	**1,386**	**2.8**	**0.03**	**0.03**

*Indicates values that have been suppressed due to the potential risk of disclosure

Table 9-10 shows the burden, infection and colonisation within low risk specialties. The highest burden was found in dermatology, care of the elderly and respiratory medicine, the highest proportion of infections was found in diabetes medicine and dermatology and the highest proportion of positive screens were found in dermatology, care of the elderly and respiratory medicine.

Table 9-10: Number and percentage of all admissions MRSA positive on admission to hospital, by low risk specialty during the study period August 2008 – July 2009, N=31,388

Admission Specialty	Total Admissions		Burden of All MRSA Positive		Admissions with MRSA Infections During Stay		Screened Positive Admissions		95% CI for Screened Positive	
Low Risk	N	%	n	%	n	%	n	%	Upper	Lower
Accident and emergency	3,142	10.0	145	4.6	*	*	65	2.1	1.57	2.57
Care of the elderly	1,506	4.8	189	12.5	5	0.3	97	6.4	5.19	7.69
Clinical Pharmacology	24	0.1	*	*	*	*	*	*	*	*
Communicable diseases	456	1.5	30	6.6	*	*	12	2.6	1.16	4.10
Dermatology	237	0.8	40	16.9	*	*	18	7.6	3.79	11.40
Diabetes medicine	115	0.4	10	8.7	*	*	*	*	0.00	4.13
Ear Nose and Throat	2,312	7.4	91	3.9	*	*	35	1.5	1.00	2.03
Endocrinology	1,667	5.3	159	9.5	*	*	68	4.1	3.05	5.10
General medicine	16,271	51.8	1,712	10.5	55	0.3	760	4.7	4.31	5.03
General practice	*	*	*	*	*	*	*	*	*	*
Hyperbaric Medicine	*	*	*	*	*	*	*	*	*	*
Infectious Diseases	482	1.5	47	9.8	1	0.2	13	2.7	1.15	4.25
Medical Other	*	*	*	*	*	*	*	*	*	*
Neurology	415	1.3	20	4.8	*	*	10	2.4	0.24	4.58
Obstetrics specialist	*	*	*	*	*	*	*	*	*	*
Orthodontics	*	*	*	*	*	*	*	*	*	*
Rehabilitation medicine	*	*	*	*	*	*	*	*	*	*
Respiratory medicine	3,553	11.3	440	12.4	6	0.2	184	5.2	4.28	6.08
Restorative dentistry	*	*	*	*	*	*	*	*	*	*
Rheumatology	774	2.5	79	10.2	*	*	39	5.0	3.46	6.62
Spinal paralysis	*	*	*	*	*	*	*	*	*	*
Stroke	417	1.3	22	5.3	1	0.2	8	1.9	0.60	3.24
Total	**31,388**	**100.0**	**2,986**	**9.5**	**76**	**0.2**	**1,311**	**4.2**	**0.04**	**0.04**

*Indicates values that have been suppressed due to the potential risk of disclosure

Within the NHS QIS HTA model the proportion of admissions to high risk and low risk was estimated by those over and less than 65 years of age. The numbers found admitted to high and low risk were found to be significantly different to those estimates (Table 9-11). A total of 64.4% of less than 65 years admissions were to high risk specialties and 35.6% of low risk specialties. Of those admissions over 65 years of age 57.8% were to high risk specialties and 42.2% of low risk admissions.

Table 9-11: Number of admissions going to a high risk and low risk specialty ward by age category over 65 and under 65s

Parameter	NHS QIS HTA Value	Pathfinder Value
Percentage of admissions going to high-risk speciality ward	30% (Under 65s) 33%(Over 65s)	64.4% (Under 65s) 57.8%(Over 65s)
Percentage of admissions going to low-risk speciality ward	70% (Under 65s) 67% (Over 65s)	35.6% (Under 65s) 42.2% (Over 65s)

9.1.6 *Aim 2 Objective 6: To evaluate the proportion of those admissions pre - emptively isolated who subsequently were identified as MRSA positive.*

Of the total admission population 0.9% (734 of all admissions) were admitted to isolation on day one of their admission, 8.9% (65/734) had screened positive at pre-admission clinic and none had been successfully decolonised. A further 65.1% (478/734) were found to be positive as a result of their admission screen. Of the remaining 191 admissions, 163 had a previous history of MRSA. Only 28 of the 734 (3.8%) patient admissions to isolation on day one of their hospital stay had no indication of MRSA (i.e. neither screened positive nor had a previous history of MRSA) (Table 9-12).

Of the 664 without a pre-admission test result who were admitted to isolation on day one of their admission 476 (71.7%) were subsequently found to be MRSA positive.

A total of 4,964 admissions were previously known positive and 529 (10.7%) were pre-emptively isolated. Altogether 954 (19.2%) of those previously known positives were isolated or cohorted during their hospital stay. Of the 2,717 admissions that screened positive 1414 (52%) were not isolated, cohorted or separated during their hospital stay.

Table 9-12: Number of admissions pre-emptively isolated or cohorted by their screening result and history of MRSA by hospital and NHS Board N= 734

Pathfinder Board	Patient Admissions Pre-emptively Isolated or Cohorted								
	All	Screened Positive at Pre-admission		Screened Positive on Admission		Screened Negative with History of MRSA		Screened Negative with no History of MRSA	
	N	n	%	n	%	n	%		%
Ayrshire and Arran	403	37	9.2	263	65.3	88	21.8	15	3.7
Grampian	155	27	17.4	122	78.7	4	2.6	2	1.3
Western Isles	176	*	*	93	52.8	71	40.3	*	*
Total	**734**	**65**	**8.9**	**478**	**65.1**	**163**	**22.2**	**28**	**3.8**

*Indicates values that have been suppressed due to the potential risk of disclosure

9.1.7 Aim 2 Objective 7: To evaluate the proportion of MRSA positive admissions who receive decolonisation.

The total number of admissions who screened positive either at admission or pre-admission clinics was 2,717 and of these 1,228 (45.2%) were given decolonisation. This varied by board from 35.5% receiving decolonisation in Grampian to 55.6% receiving decolonisation in Ayrshire and Arran (Table 9-13).

Table 9-13: Number and percentage of MRSA positive patient admissions receiving decolonisation as a result of admission screen, by health board during the study period August 2008 – July 2009, N=2,717

Pathfinder Board	MRSA Screen Positive Patient Admissions (from admission or preadmission screen)	MRSA Screen Positive Patient Admissions Receiving Decolonisation as a Result of Admission Screen	
	N	n	%
Ayrshire and Arran	1,244	692	55.6
Grampian	1,322	469	35.5
Western Isles	151	67	44.4
Total	**2,717**	**1,228**	**45.2**

Multivariable logistic regression, clustered by patient admissions, was carried out to investigate the variables affecting decolonisation on the 2,717 positive screens. Variables included in the model were age at admission, type of admission (elective or emergency), frequency of admission in the study year, length of hospital stay, hospital and specialty admitted to and where the patient was admitted from (home or not). The most significant variable was the length of stay, followed by hospital and attendance at a pre-admission clinic.

To allow for the potential confounding effect of a short length of stay, a new variable, "time to act", was generated to measure the time (in units of overnight stays) between the screening result being reported back and the patient being discharged. Admissions who attend a pre-admission clinic have an opportunity to be decolonised pre-admission. To investigate decolonisation further, those who attended pre-admission clinics were analysed separately from those who were admitted directly. Of the 2,717 positive admissions 135 were identified by a pre-admission clinic screen 13.3% (18/135) of them were successfully decolonised and 47.7% (63/135) were initiated on decolonisation. The remaining 2,575 did not attend pre-admission clinics and of those 1,140 (44.3%) were initiated on decolonisation.

For those who screened positive and did not attend a pre-admission clinic the length of hospital stay was the most important independent predictor for being initiated on decolonisation. Length of hospital stay is investigated further in Aim 2 Objective 8. Among the 2,572 admissions (who did not attend pre-admission clinic) the percentage decolonised among those discharged on the same day, or the day following, the date the result became known was 8.3% compared with 66.5% among those who remained in hospital for two or more nights following the result becoming known.

Of the 2,572 admissions which screened positive on admission 1,572 remained in hospital for two or more nights after the MRSA screen result was reported and 67.2% of this group were decolonised. Among this group the hospital of admission was the most important variable. The highest proportion of admissions that initiated decolonisation was in Ayr (86.7%), followed by Crosshouse (76.8%); the lowest proportion were found in Aberdeen Royal (53.8%) and Woodend Hospital (50%).

Reasons for not decolonising colonised admissions are given under Aim 2 Objective 12.

9.1.8 Aim 2 Objective 8: To evaluate the distribution of patient length of stay by specialty i.e. who can be screened and treated.

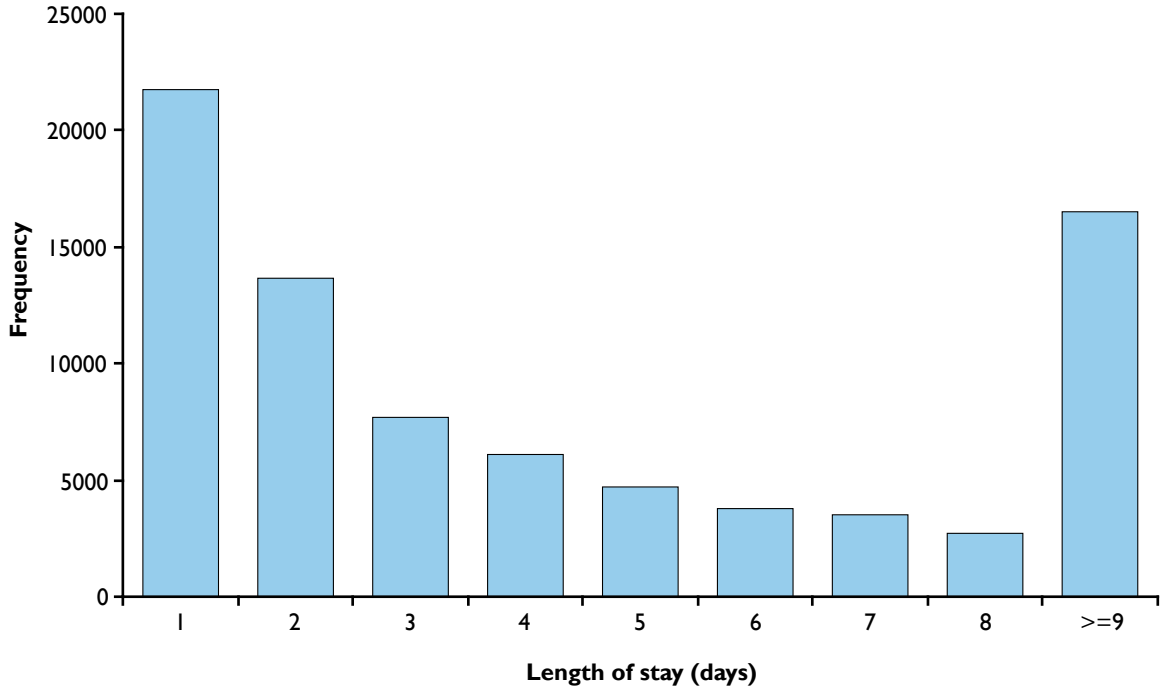
Length of hospital stay was known for 80,614 of the 81,438 admissions. The median length of stay for Ayrshire and Arran and Grampian NHS Boards was three days. Western Isles was four days. Longest length of stay was recorded in Grampian at 361 days. Nonetheless, for the entire pathfinder sample 25% of admissions had a length of stay of just one day and 75% of admissions less than seven days.

Table 9-14: Descriptive statistics for length of stay by Pathfinder Board N= 80,614

	Length of Stay (days)			
	N	Range	Median	IQR
Ayr and Arran	34,269	1 day - 333 days	3	1day - 8days
Grampian	43,624	1 day - 361 days	3	1 day- 7 days
Western isles	2,721	1 day - 308 days	4	2 days - 8 days

Figure 9-6 shows the numbers of admissions whose stay was up to nine days, this reflects the short length of stay for the majority of admissions. Forty four percent (n=35,451) of total admissions were discharged less than two days after admission.

Figure 9-6: Histogram showing length of stay by days. N=80,641 for combined Pathfinder Boards



Multivariable regression, clustered by patient admissions, showed that length of stay was most affected by the age of the patient and the specialty of admission. Median hospital stay rose from two nights in the under 49 year age group to four nights in the 65-79 years age group and six nights in the over 80 years age group. Length of stay also varies by specialty; Table 9-15 and Figure 9-7 show each specialty and the number and proportion of admissions by length of stay for each clinical area.

Table 9-15: Length of stay (days) by specialty of admission among N=80,614 admissions for whom length of stay was known, during the study period August 2008 – July 2009

Specialty	Length of Stay				
	1 night	2-3 nights	4-7 nights	8+ nights	Not known
Accident and emergency	2,353	441	159	144	45
Anaesthesia/ICU	66	52	58	186	7
Cardiac surgery	37	53	63	465	5
Cardiology	1,065	1,043	1,112	1,113	43
Care of the elderly	295	282	336	587	6
Clinical Pharmacology	*	12	*	5	*
Communicable diseases	55	140	126	133	*
Coronary Care Unit	95	90	99	61	*
Dermatology	9	13	50	162	*
Diabetes medicine	15	22	31	45	*
Ear, Nose and Throat	1,185	834	147	117	29
Endocrinology	388	307	437	522	13
Gastroenterology	976	953	940	1,119	38
General medicine	4,020	3,504	3,794	4,799	154
General practice	*	*	*	*	*
General surgery (excluding vascular)	3,335	4,048	2,643	2,352	137
Gynaecology	967	1,137	1,047	249	45
Haematology	225	153	147	239	7
High dependency unit	145	130	188	246	8
Hyperbaric Medicine	*	*	*	*	*
Infectious disease	95	95	108	182	*
Maxillofacial	320	348	90	82	11
Medical oncology	227	234	156	150	12
Medical other	*	*	*	*	*
Nephrology/Renal	536	551	540	817	27
Neurology	75	106	110	119	5

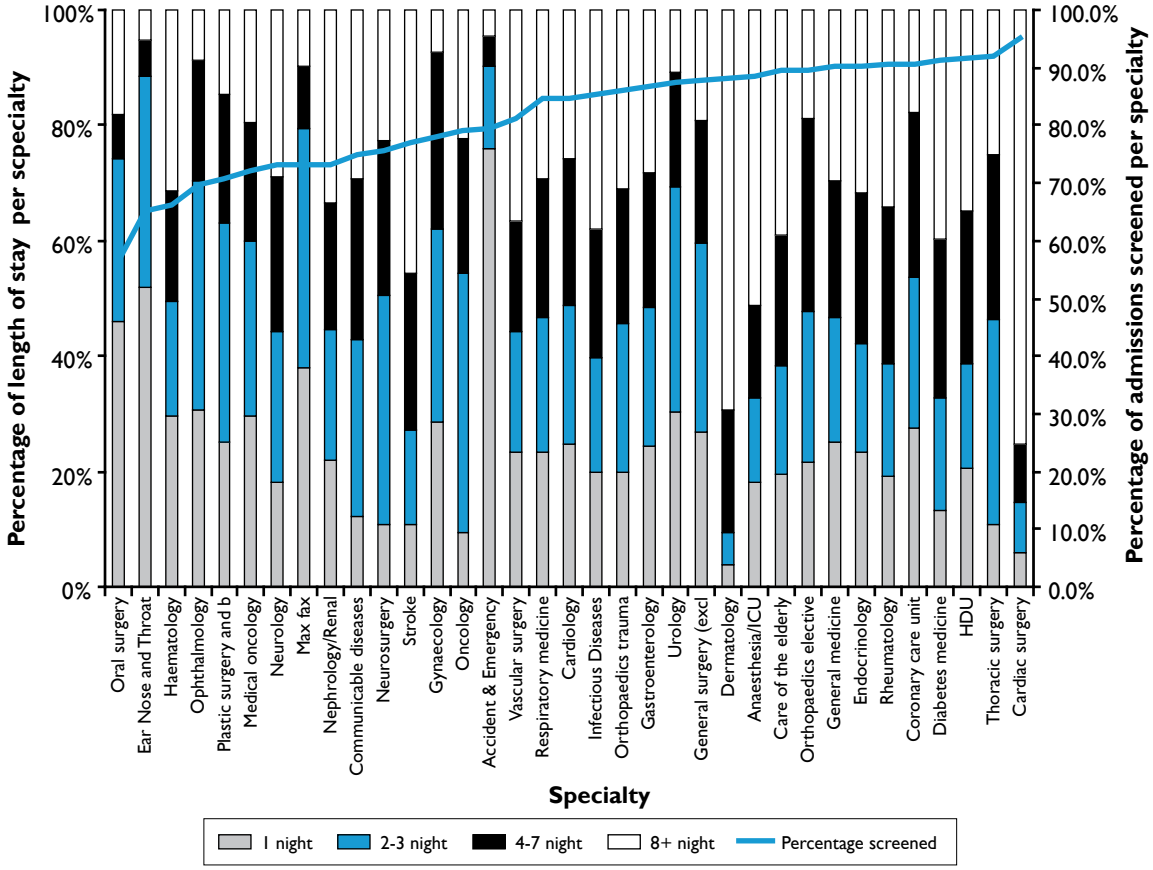
Specialty	Length of Stay				
	1 night	2-3 nights	4-7 nights	8+ nights	Not known
Neurosurgery	95	354	237	202	17
Obstetrics specialist	*	*	*	*	*
Oncology	57	274	142	135	*
Ophthalmology	280	364	189	80	7
Oral surgery and medicine	18	11	*	7	*
Orthodontics	*	*	*	*	*
Orthopaedics elective	988	1,179	1,526	854	34
Orthopaedics trauma	940	1,238	1,116	1,472	47
Plastic surgery and burns	194	292	173	112	6
Rehabilitation medicine	*	*	*	*	*
Respiratory medicine	819	834	849	1,029	22
Restorative dentistry	*	*	*	*	*
Rheumatology	147	149	208	262	8
Spinal paralysis	*	*	*	*	*
Stroke	44	67	112	187	7
Thoracic surgery	33	108	87	77	*
Urology	1,298	1,667	861	459	51
Vascular surgery	328	296	268	514	14
Not known	33	9	*	*	*

*Indicates values that have been suppressed due to the potential risk of disclosure

Figure 9-7 shows the specialty length of stay grouping as a proportion of the total specialty admission population when specialty population was greater than 50 admissions during the project and where a valid specialty was recorded (N = 80,284). These have been ranked by screening compliance which shows an incremental increase from left to right.

Specialties such as ear nose and throat, oral surgery, ophthalmology and maxillary facial surgery had a higher proportion of admissions remaining as in-patients for three nights or less and these units also had the lowest screening compliance. Units with a greater proportion of admissions staying for eight nights or more were cardiac surgery units, dermatology units and intensive care units. Screening compliance was markedly higher in these units.

Figure 9-7: Proportion of total admissions screened by specialty N=80,284



9.1.9 Aim 2 Objective 9: To describe the number of single bed rooms available per ward.

Overall the median number of single rooms per ward was found to be 4.5 in Ayrshire and Arran, 4.5 in Grampian, and slightly higher in the Western Isles with an average of 5.0 rooms per ward.

Table 9-16: Number of single rooms available per ward in pathfinder hospitals and NHS Boards

Pathfinder Board	Mean	Median	IQR
Grampian	4.5	4.0	4
Ayrshire	4.4	4.5	2
Western Isles	5.0	5.0	2

9.1.10 Aim 2 Objective 10: To evaluate the proportion of admissions identified as colonised who were isolated or cohorted.

Table 9-17 shows the number of patient admissions who screened positive on admission and whether or not they were isolated, separated or cohorted during their stay by pathfinder board. It shows that 1,280/2,717 (47.1%) were isolated at some point during their stay, although it varies by health board with 33.1% in Grampian to 79.5% in Western Isles. Only small numbers of admissions were cohorted or separated giving an overall number of 48.0% of admissions being isolated cohorted or separated during their stay.

Table 9-17: Number and percentage of MRSA positive admissions isolated, cohorted or separated during admission, by health board during the study period August 2008 – July 2009, N=2,717

Pathfinder Board	MRSA Positive on Admission	Admissions Isolated During Stay		Admissions Cohorted or separated During Stay		Admissions Isolated, Cohorted or Separated During Stay	
	N	n	%	n	%	n	%
Ayrshire and Arran	1,244	722	58.0	5	0.4	723	58.1
Grampian	1,322	438	33.1	17	1.3	446	33.7
Western Isles	151	120	79.5	27	17.9	134	88.7
Total	**2,717**	**1,280**	**47.1**	**49**	**1.8**	**1,303**	**48.0**

Multivariable logistic regression, clustered by patient admissions, was carried out to investigate those isolated or cohorted among those who screened positive on admission. All 2,717 admissions screening positive were included in the regression. The outcome variable was "isolated or cohorted" at any time during their stay.

Variables included in the model were age at admission, gender, type of admission (elective or emergency), frequency of admission in the study year, hospital and specialty admitted to, where the patient was admitted from (home or not) and whether or not the patient was a "previously known positive". Interactions with age group, gender and type of admission were tested and found to be not significant.

The significant variables are displayed in Table 9-18. In order of importance the variables that independently best predicted isolated or cohorted were length of stay, hospital, specialty and admission from other than home.

Higher odds of being isolated or cohorted were associated with admissions with a length of stay greater than four nights. Specifically, admissions staying four to seven nights have 7.6 times higher odds than the baseline of one night while the admissions staying more than eight nights have 14.5 times higher odds than the baseline.

The limited number of patients who were isolated reflects the length of stay of patients, facilities available within each hospital and the prevalence of MRSA colonisation within each hospital specialty.

Table 9-18: Results of multivariable clustered logistic regression analyses of being isolated (or cohorted) among N=1,303 admissions who screened positive on admission, during the study period August 2008 – July 2009

Variable	Subgroup	Regression Coefficient (standard error)	P Value	Odds Ratio (95% CI)
Hospital	Ayr Hospital (baseline)	0	-	
	Aberdeen Royal Infirmary	-1.578 0.134	<0.0001	0.206 (0.159 - 0.268)
	Woodend	0.002 0.429	0.997	1.002 (0.432 - 2.322)
	Crosshouse	-0.783 0.147	<0.0001	0.457 (0.342 - 0.61)
	W Isles	1.984 0.368	<0.0001	7.269 (3.53 - 14.968)
	Uist and Barra	1.467 0.752	0.051	4.339 (0.993 - 18.961)
Length of Stay	LOS 1 night (baseline)	0	-	
	2-3 nights	0.606 0.191	0.002	1.834 (1.259 - 2.669)
	4-7 nights	2.031 0.187	<0.0001	7.622 (5.282 - 10.998)
	8+ nights	2.676 0.178	<0.0001	14.534 (10.246 - 20.618)
Specialty	Surgery (baseline)	0	-	
	Accident and Emergency	-2.247 0.514	<0.0001	0.106 (0.039 - 0.29)
	Cardiology	-0.467 0.229	0.041	0.627 (0.4 - 0.982)
	Care of the Elderly	-1.254 0.283	<0.0001	0.285 (0.164 - 0.497)
	Intensive care/HDU	-0.934 0.374	0.013	0.393 (0.189 - 0.818)
	Medicine	-1.322 0.141	<0.0001	0.267 (0.202 - 0.352)
	Oncology	-0.514 0.372	0.167	0.598 (0.288 - 1.24)
	Orthopaedic	-0.247 0.209	0.238	0.781 (0.518 - 1.178)
	Renal	-0.057 0.288	0.843	0.944 (0.537 - 1.661)
Admitted from	Admitted from home (baseline)	0	-	
	Not admitted from home	0.446 0.132	<0.0001	1.562 (1.205 - 2.026)
	constant	-0.289 0.193	-	
Log Likelihood: -1253.421		Degrees of Freedom 18		AIC : 2545.842

Table 9-19 shows the number of admissions, the percent of admissions, number and percentage of isolated or cohorted among those screened positive, for the variables which where found to be important independent predictors of being isolated or cohorted in the regression analyses.

Table 9-19 shows that admissions with length of stay greater than eight nights accounted for 42.5% of the overall positive screens and 64.6% of positive admission screens staying eight or more nights were isolated, cohorted or separated. A total of 53.8% of admissions staying for four to seven nights were isolated or cohorted with those staying two to three nights only being isolated or cohorted in 28.6% of cases.

Table 9-19: Number and percentage of admissions, and number and percentage isolated (or cohorted) among N=2717 admissions who screened positive on admission during the study period August 2008 - July 2009; by hospital and length of stay (days)

Variable	Subgroup	Admissions Screened Positive		Isolated or cohorted	
		N	%	n	%
Length of Stay	1 night	382	14.1	69	18.1
	2-3 nights	528	19.4	151	28.6
	4-7 nights	619	22.8	333	53.8
	8+ nights	1155	42.5	741	64.2
	Not known	33	1.2	9	27.3
Hospital	Aberdeen Royal Infirmary	1279	47.1	417	32.6
	Woodend	43	1.6	29	67.4
	Ayr	625	23.0	404	64.6
	Crosshouse	619	22.8	319	51.5
	W Isles	136	5.0	122	89.7
	Uist and Barra	15	0.6	12	80.0
Specialty	Accident and Emergency	65	2.4	6	9.2
	Cardiology	145	5.3	86	59.3
	Care of the Elderly	97	3.6	58	59.8
	Anaesthesia/ICU/HDU	58	2.1	42	72.4
	Medicine	1306	48.1	522	40.0
	Oncology	42	1.5	18	42.9
	Orthopaedic	220	8.1	146	66.4
	Nephrology/Renal	100	3.7	66	66.0
	Surgery	681	25.1	359	52.7
Admitted from	Admitted from home	2238	82.4	1022	45.7
	Not admitted from home	479	17.6	281	58.7

9.1.11 Aim 2 Objective 11: To describe the reasons for not isolating colonised patient admissions

The reasons for a patient leaving isolation or cohort was recorded by the data collection teams. Where reasons for exiting from isolation were recorded were examined which provide an indication of the issues encountered while isolating admissions. One of the main reasons for not continuing with isolation was the patient was discharged (92.4%, 934/1,011). The next most common reason was that the room became unavailable (1.5%, 15/1,011) followed by the need for observation which accounted for 1.1% (11/1,011) of responses. Of the total admissions who were found positive for MRSA colonisation none refused to be isolated, although 0.2% (13/6,280) of admissions who were within the total burden group refused to be isolated.

Table 9-20: Reasons where recorded for MRSA positive patient admissions being moved from isolation or cohort during the study period August 2008 – July 2009 where reason for leaving isolation or cohort was recorded N=1,011

Reason for Exit of Isolation/Cohort/Separated	MRSA screen positive admissions Moved from Isolation or Cohort	
	N	%
Discharged	934	92.4
Room not available	15	1.5
Observation required	11	1.1
Other	51	5.0
Total	**1,011**	**100.0**

9.1.12 Aim 2 Objective 12: To evaluate the proportion of admissions identified as colonised and successfully decolonised and the reasons for not decolonising admissions with a positive screen.

As in Aim 2 Objective 7 successful decolonisation was examined (which was defined as three negative screens recorded either before admission or before discharge) separately for those who attended a pre-admission clinic and those who did not. From Aim 2 Objective 7 it was shown that 1,215 admissions were initiated on decolonisation treatment 63 before admission and 1,152 during the hospital stay. Of those who initiated decolonisation, only 8.1% (98/1,215) were known to have subsequently had three negative screens, 18 prior to admission and 80 prior to discharge.

Of the admissions identified as positive for MRSA at admission or pre-admission clinics 44.7% (1,215/2,717) initiated decolonisation. There was little variation in the proportions receiving decolonisation treatment by risk category of admission specialty. 3.6% of all admission found to be positive were successfully decolonised (98/2717). Of the admissions who initiated decolonisation during their hospital stay 6.9% (80/1,152) were successfully decolonised.

The majority of admissions did not receive decolonisation therapy due to discharge prior to availability of result (84.8%). Other reasons included clinical decision, on alternative antibiotic therapy for other infection, skin conditions and chronic MRSA.

Table 9-21: Reasons for patient admissions not receiving decolonisation treatments during the study period August 2008 – July 2009, for those positive admissions where reason for not decolonising was recorded N=1,131

Reason for Not Decolonising Patient Admissions	Admissions Not Decolonised	
	N	%
Chronic MRSA	5	0.4
Clinical decision	103	9.1
Died before results returned	6	0.5
Discharged before results returned	959	84.8
Other	33	2.9
Skin condition	8	0.7
Too unwell	5	0.4
Undergoing treatment for infection	12	1.1
Total	**1,131**	**100.0**

9.1.13 Aim 2 Objective 13: To describe the reasons why all inpatient admissions were not screened.

In Aim 2 Objective 1 it was shown that among elective admissions who attend pre-admission clinics the hospital and specialty of admission were the best predictors of screening.

In Aim 2 Objective 2 it was shown that among emergency admissions (and transfers between hospitals) hospital and specialty were important predictors of screening but so were length of stay, month of admission and whether or not the patient was admitted from home.

Reasons some admissions were not screened are presented in Table 9-23. Of the total patient population 85.3% (69,445/81,438) were screened at pre-admission clinics or on admission.

Table 9-22: Number and percentage of admissions, and number and percentage screened among the hospitals and health boards during the study period August 2008 - July 2009 N=81,438

Pathfinder Board	Total Admissions		Admissions Screened	
	N	%	n	%
Ayrshire and Arran	34,613	42.5	30,367	87.7
Ayr Hospital	15,115	18.6	13,652	90.3
Crosshouse Hospital	19,498	23.9	16,715	85.7
Grampian	44,080	54.1	36,479	82.8
Aberdeen Royal Infirmary	40,848	50.2	33,581	82.2
Woodend Hospital	3,232	4.0	2,898	89.7
Western Isles	2,745	3.4	2,599	94.7
Western Isles Hospital	2,310	2.8	2,173	94.1
Uist and Barra Hospital	435	0.5	426	97.9
Total	**81,438**	**100**	**69,445**	**85.3**

The main reason for not obtaining a screening sample was because a screening opportunity was 'missed'. At 97.4% (10,458/10,739) of the total of samples where a reason was provided this was by far the most common reason for not obtaining a screening sample. Refusal to have a nasal screen carried out was accountable for only a small proportion of screening not undertaken at 0.3% (35/10,739).

It is important to note that these data reflect the completed forms which were recorded and sent to HPS it is expected that screening compliance itself was higher.

Table 9-23: Those admissions not screened and the reasons for not screening for those admissions where this was recorded N=10,739

Reason for not screening	Admissions Not Screened	
	N	%
Missed	10,458	97.4
Too unwell	55	0.5
Nasal trauma	52	0.5
Other	51	0.5
Swab documentation not completed	46	0.4
Refused	35	0.3
Unable to consent	24	0.2
Nasal device	11	0.1
Died before screen taken	7	0.1
	10,739	**100.0**

Figure 9-8 shows the percentage of each specialty where patient admissions were not screened due to 'missed' opportunity. The percentage of admission missed varied by specialty. Those units historically associated with higher MRSA risk specialist units: cardiac surgery, coronary care, intensive care, and high dependency units had proportionally lower numbers of 'missed' admissions than units with lower risk and a high turnover of patient admissions such as oral surgery, ear, nose and throat (ENT), ophthalmology and maxillary facial surgery. General medicine and general surgery units however have the highest turnover of patients and had fewer admissions who were 'missed'.

Figure 9-8: Percentage of total admissions with known admission specialty which were missed by specialty N= 10,469

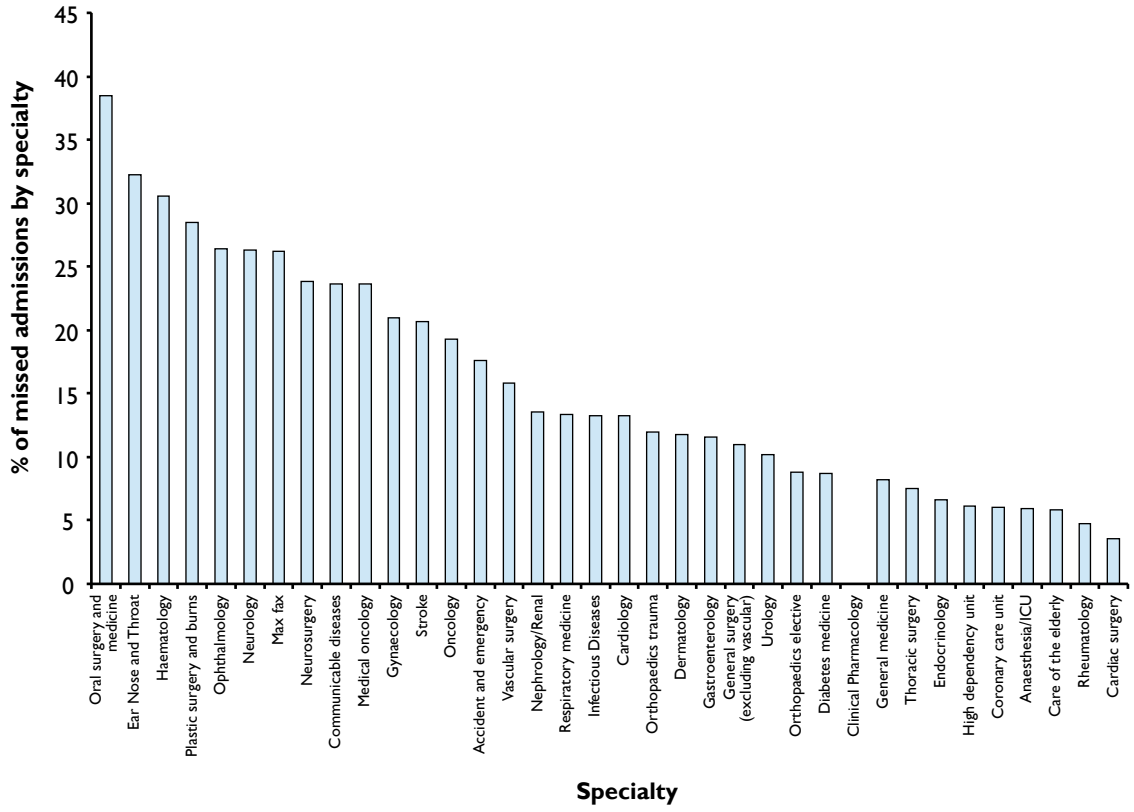
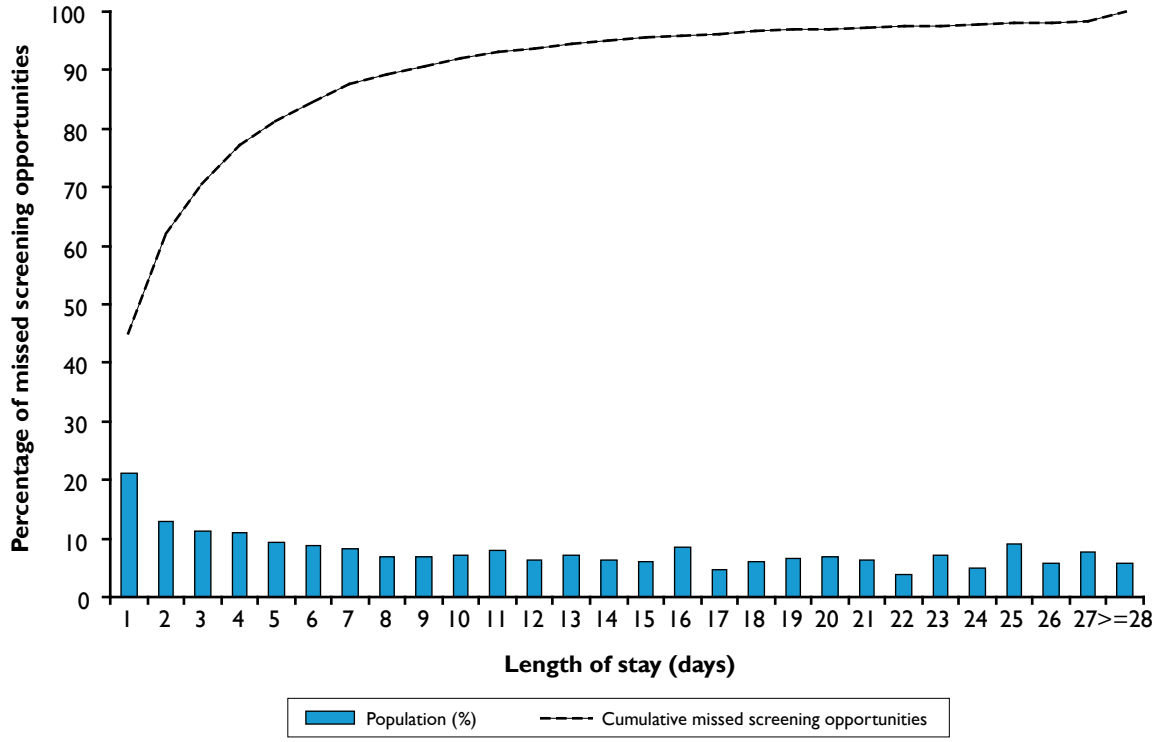


Figure 9-9 shows the proportion of patients missed by length of stay and the cumulative proportion missing by length of stay. This indicates that most of the missed admissions (approximately 70%) had a length of stay of three days or less. This shows that although admissions staying for three days or less make up a large proportion of those missed there are still a proportion of admissions who stay for a longer period. Within the protocol however patients who were missed were screened when they were identified as having been missed, this was not recorded as an admission screen and therefore would not have been recorded by the data collectors.

Figure 9-9: Percentage of total admissions missed with known length of stay by length of stay N=10,273



9.1.14 *Aim 2 Objective 14/15: To examine the potential for new technologies or approaches to offer better value for money*

An extensive literature review was undertaken looking at publications since the NHS QIS HTA to review technologies which were either under contract on UK National procurement contracts or had been used in studies for MRSA Screening studies. Table 9-24 summarises the findings of this review. A single tick represents an acceptable response, two ticks a good, and three ticks represent a very positive response. This summary will be discussed in greater detail within the discussion section of the report.

Table 9-24: Comparison of test types

Test Type	Accuracy	Speed of process	Easy of use	High throughput	Cost of test	Laboratory can currently accommodate	Contribute to patient care pathways
PCR "Laboratory"	✓✓	✓✓	✓✓	✓✓	✓	✓✓	✓✓
PCR "Near patient"	✓✓	✓✓✓	✓✓✓	✓	✓	✓✓	✓✓✓
Agar	✓✓✓	✓	✓✓	✓✓✓	✓✓✓	✓✓	✓

9.1.15 Aim 2 Objective 16: To quantify the time taken to carry out swab screening versus clinical risk assessment for MRSA colonisation

The MRSA screening team within the Western Isles undertook a short study to assess relative time taken for nasal screen from start to finish compared to a short clinical risk assessment comprising six questions. This work was undertaken as a preparation for the special studies which are planned for January 2010. A sample of patients who undertook a nasal swab was compared to a sample of patients who underwent a clinical risk assessment. The time taken to carry out risk assessment and different swabbing regimes either full body swabbing (nasal, throat, axilla and perineum) or nasal swabbing alone are shown in Table 9-25. It is important to note that the clinical setting within the Western Isles is quite different from the other Pathfinder Boards in that size of hospital, patient population and patient turnover is quite different, the relative times comparing one procedure to the other should be comparable.

The median time taken to complete a clinical risk assessment comprising of six questions and verification of results by case note review was 360 second (six minutes).

The median time taken to undertake nasal swabbing alone but including preparation and completion of documentation for sample transfer to the laboratory was 330 seconds (5.5 minutes).

The time taken for full body swabbing including preparation and completion of documentation for transfer to the laboratory was 570 seconds (9.5 minutes).

Table 9-25: Descriptive statistics for time taken in seconds for clinical risk assessment, nasal swabbing and full body swabbing N= 96

	Median	25th Percentile	75th Percentile	N
Time Taken for CRA (seconds)	360	240	660	97
Total Time Taken for Nasal Swab (seconds)	290	220	435	97
Total Time Taken for Full Body Swab (seconds)	570	430	795	62

Since the data were not normally distributed a Wilcoxin matched-pairs signed-ranks test was used to test whether there was statistical difference in the time taken for nasal swabbing and clinical risk assessment. We thus, tested the assumption that the two distributions were the same.

H0: time for nasal swabbing = time for clinical risk assessment

The results of this test were significant ($z = -2.346$, $p = 0.019$) indicating that the two

9.1.16 Aim 2 Objective 17: To carry out an economic analysis of the cost effectiveness of the programme in the context of other possible interventions to reduce MRSA in NHSScotland

A balance sheet is presented in Table 9-26 comparing the evidence to support universal screening against the current policy of targeting screening, based on the findings of the Clinical effectiveness and this volume of the report.

Table 9-26: Balance sheet Comparison of Current policy of targeted screening and Universal screening

For Universal Screening	Against Universal screening
Generally acceptable to patients and public	Additional initial capital investment for laboratory alterations and equipment
Generally acceptable to staff	Additional investment in consumables over five years
Statistically significant reduction in colonised patients as observed within Pathfinder study	Requirement for additional health board staff to implement and maintain universal screening
Statistically significant reduction in patients with infection as observed within Pathfinder study	Short length of stay make interventions difficult
Avoidance of damage and distress	Demand for facilities makes isolation difficult
Decrease in use of isolation facilities for MRSA over time therefore available for other HAI	Chromogenic agar turn around times combined with short length of stay makes intervention for short stay patients difficult
Equitable for all patients	Monitoring of effectiveness at national level will require additional resources over next five years
Practical to implement as all patients undergo same admission protocol	Consideration must be given to value for money in the context of the current financial situation
Decrease in costs over five years as projected by model	
Considerable cost attributable to MRSA infection without screening	

10 Comparison of NHS QIS HTA model with Pathfinder results

Table 10-1: Assumptions made in the development of the NHS QIS HTA model Strategy 2 and subsequent findings during the Pathfinder Project.

NHS QIS HTA	Pathfinder
All elective patients are screened at pre-admission or admission	A proportion (Table 9-1) (24.9%) of elective admissions are screened at pre-admission clinics
All emergency patients are screened on admission	A proportion (85.1%) of emergency admissions are screened on admission
Patients found positive at pre-admission clinics are admitted to hospital and isolated on admission and undertake decolonisation on arrival	A proportion (48.1%) ([3] Aim 1 objective 6) of admissions found positive at pre-admission clinics are provided with decolonisation treatment before admission and 18% of those found positive are decolonised before admission
Patients not attending pre-admission clinics undergo screening on admission to the emergency ward and wait there for their results of the test. The length of stay is two days during which time the swab test is reported back. Therefore patients are not admitted to a specialty ward until their MRSA status is known	Admissions are often admitted to ward before their MRSA status is known. (See Aim 2 objective 6).
During their stay on the emergency admissions ward any patient with a positive swab screening is isolated where possible	Patients are often admitted to a specialty ward before their MRSA status is known, very few admissions receive results while in an emergency receiving unit
Other than grouping according to high risk or low risk specialty unit, no further distinction was made between ward types	Variation within risk category was found to be significant at specialty level, included within the analysis of Pathfinder data was broad specialty type.
Clinical risk assessment, MRSA screening, isolation and decolonisation policies differ between ward types (i.e. high risk or low risk specialty units)	Screening policies currently differ from specialty to specialty and wards type, within the Pathfinder study it was found that this is not optimal for implementation and the preferred option was to implement a consistent approach [4]
Risk category is defined by specialty the patient is being treated in and this remains constant throughout patients stay in hospital	Risk category is defined by the specialty of the clinician treating the patient on admission but this varies throughout the patients stay in hospital. For example a patient admitted to medical receiving ward undergoes diagnostic tests and is subsequently treated in coronary care
Minimum turn around time for Chromogenic agar is 24 hours and maximum is 48 hours	Turn around time varies by hospital depending on laboratory services, time of admission and test result. The median turn around time for a negative result found in the Pathfinder was 27.6 hours (Figure 9-1) and median turn around time for a positive result was 47.6 hours (Figure 9-2).

NHS QIS HTA	Pathfinder
Isolation rooms are used solely for MRSA colonised patients	Isolation rooms are in demand and are required for isolation of patients with a range of conditions
Isolation of all MRSA patients is possible	In many cases isolation is not possible, patient cohorting is the next option.
The economic model simplified patient management options to include either being housed in a single-bed isolation room or in a bed on an open ward. A literature search found no evidence that patient cohorting was effective in reducing MRSA transmission. Thus cohorting was excluded as a patient management option in the model. Beds in other locations were considered as 'bed in open ward' for modelling purposes	In many cases isolation is not possible, patient cohorting is the next option. 48.0% of admissions found positive were isolated or cohorted during their stay (Table 9-17). There is some evidence for Nurse cohorting [18] but no evidence for patient cohorting
Patients once in isolation remain there until receipt of three negative screens or discharge	Patient management is based on individual assessment and priorities for isolation rooms. Patients are moved out of isolation rooms to provide isolation to patients with a greater requirement prior to receipt of three negative screens. (Table 9-20)
MRSA colonised patients admitted to a high risk specialty wards undergo one round of decolonisation with subsequent test to see if decolonisation is successful patients admitted to a low risk specialty do not undergo decolonisation	All admissions found to be MRSA colonised undergo decolonisation regardless of the specialty of the ward [4]. Many admissions have been discharged before they are able to complete decolonisation treatment or undergo a follow up test. (Table 9-21)
For the purposes of the economic model, it has been assumed that 0.6% of colonised patients being admitted to low-risk specialties will develop infection and 3.0% of those admitted to high-risk specialties will develop infection.	Within the pathfinder study 0.9% of high risk admissions became infected and 0.7% of low risk admissions developed MRSA infection (Table 10-10)
Admissions and discharges, occurred from and to a common community pool, thus by default the same admission MRSA colonisation prevalence occurred in patients admitted to all wards	MRSA colonisation prevalence varied significantly between patients admitted to different specialty wards. (Table 9-10)

10.1 Economic parameters update

The total costs within the economic model in the HTA were updated to reflect changes in estimates of staffing costs and consumables, for the following procedures:

- patient swabbing
- laboratory tests on swab samples
- decolonisation of patients
- contact precautions
- cost of hospital inpatient stay in isolation rooms

10.1.1 Staff costs

The estimates of staffing costs were updated by mapping each staff grade to the equivalent Agenda for Change band from information supplied by NHS Quality Improvement Scotland [19]. Staff salary costs were taken from 2009/2010 NHSScotland pay scales. The distributions of staff across different bands were obtained from the ISD workforce statistics data set.

10.1.2 Patient swabbing

The updated cost for consumables was supplied by NHS National Procurement [20] and reflects the national contract for Laboratory Sundries.

Table 10-2: Costs associated with taking patient swab samples

Procedure	Tertiary general hospital	Large general hospital
Swabbing patients	£3.05	£3.20

10.2 Laboratory tests

10.2.1 Screening agar and chromogenic agar testing

The cost of laboratory consumables was increased by 1.5% following advice from NHS National Procurement [21].

The updated cost for samples sent to the MRSA Reference Laboratory for confirmation assumed that 5% of positive samples are a sent to the MRSA Reference Laboratory, reduced from 10% in the HTA. The total cost attributable to each included carriage only, thus there were assumed to be no associated staff and consumable costs per sample. The cost for carriage of samples to the Reference Laboratory was provided by Medical Microbiology, [22].

Costs of positive and negative laboratory tests, per sample, are detailed in Table 10-3 . For samples found to be negative, all stages of the test are not required resulting in a lower average cost.

Table 10-3: Cost per sample

Testing regimen	Result	Cost per sample
Chromogenic agar + slide latex + disc	Positive	£7.24
Chromogenic agar + slide latex + disc	Negative	£4.24
Real-time PCR		£27.34

10.2.2 Real-time PCR

The cost estimates presented are for a laboratory based PCR system. Estimates of consumables required were provided by the manufacturer [23]. Consumables included the testing kit and cost of servicing the equipment. Laboratory overheads were included in the final cost. The cost per swab sample for a real-time PCR test was estimated as £27.34 and was the same for negative and positive samples.

10.2.3 Contact precautions

The cost for consumables was supplied by NHS National Procurement [20] and remained unchanged from those provided for the HTA.

Table 10-4: Costs associated with contact precautions

Procedure	Tertiary referral hospital	Large general hospital – High risk
Contact precautions	£18.58	£19.53

10.2.4 Costs associated with inpatient stay

The Median Index of Public Sector Building Tender Prices (MIPS) Index was used to update the incremental cost of providing and servicing the additional space associated with single beds in isolation rooms compared to open wards, to reflect current market conditions.

Table 10-5: Additional daily costs associated with single rooms

Procedure	Tertiary general hospital	Large general hospital
Isolation room	£76.94	£88.43

10.2.5 Decolonisation treatment

The updated costs for the decolonisation treatments administered were taken from the British National Formulary 58 [24] and NHS National Procurement Contracts.

Table 10-6: Decolonisation resource requirement

Location	Treatment	Daily staff time spent administering treatment (minutes per patient)
Skin	Body wash	10
Nose	Nasal ointment	5

The total cost was assumed to be £54.01 for each course of treatment consisting of five applications at a cost of £10.80 each.

There has been a considerable volume of data collected during the Pathfinder which can inform both the parameter estimates of the NHS QIS HTA model, but also the design of the model. Table 10-7 shows a comparison between the NHS QIS HTA theoretical model tertiary referral hospital and large general hospital and the size of the Pathfinder hospitals being studied.

Table 10-7: Comparison of size of hospitals with NHSQIS HTA and Pathfinder Project

	NHS QIS HTA Tertiary Referral	NHS QIS HTA Large general	Pathfinder Tertiary Referral	Pathfinder Large general
Bed numbers	840	480	893 beds	470 average beds
Source data	Average from Scottish Health Service Costs 2005 (ISD)	Average from Scottish Health Service Costs 2005 (ISD)	Aberdeen Royal Infirmary	Ayr Hospital 350 beds Crosshouse Hospital 590 beds

Table 10-8 shows the NHS QIS HTA parameters common to both tertiary referral hospitals and large general hospitals used within the NHS QIS HTA and the parameters measured within the Pathfinder project, which were used to repopulate the model within Task 2. These values are taken from the aggregated Pathfinder data. The most significant differences are the proportions of elective admissions attending and being screened at pre-admission clinics; the proportion of admissions direct to hospital without undertaking pre-admission screen; the proportion of admissions over and less than sixty five years of age admitted to high and low risk specialties and MRSA colonisation prevalence on admission at the start of the study.

Table 10-8: Parameter values common to both tertiary referral hospitals and large general hospital settings used in NHS QIS HTA and parameters collected from Pathfinder Project. (NHS QIS HTA Table 6-16)

Parameter	NHS QIS HTA Value	Pathfinder Value	Source
Readmission rate patients at low-risk of readmission colonised patients (daily)	0.00063 (95% CI 0.00058 to 0.00068)	0.00063 (95% CI 0.00058 to 0.00068)	Cooper *et al*[1]
Readmission rate – High-risk colonised patients (daily)	0.00653 (Under 65s) 0.00645(Over 65s)	0.00653 (Under 65s) 0.00645(Over 65s)	Cooper *et al*[1]
Readmission rate – Low-risk non-colonised patients (daily)	0.00063 (95% CI 0.00054 to 0.00060)	0.00063 (95% CI 0.00054 to 0.00060)	From inpatient records for year ended 31 March 2005. [25]
Readmission rate – High-risk, non-colonised patients (daily)	0.00653 (Under 65s) 0.00645 (Over 65s)	0.00653 (Under 65s) 0.00645 (Over 65s)	From inpatient records for year ended 31 March 2005. [25]
Sensitivity of clinical risk assessment	0.875	0.875	NHS QIS HTA [2] Cooper *et al*[1]
False-positive rate for clinical risk assessment	0.64	0.64	NHS QIS HTA [2] Cooper *et al*[1]
Sensitivity of swab tests	Chromogenic agar: 0.98 Real time PCR: 0.96	Chromogenic agar: 0.98 Real time PCR: 0.96	NHS QIS HTA Table 5-7 [2] Nsira *et al* [26] Stokes *et al*[27]
False-positive rates of swab tests	Chromogenic agar :0.002 Real time PCR: 0.05	Chromogenic agar: 0.002 Real time PCR: 0.05	NHS QIS HTA Table 5-7 [2] Nsira *et al* [26] Stokes *et al* [27]
Turnaround time for swab test results (hours)	Chromogenic agar: 24 h Real time PCR: 24 hour	Chromogenic agar (positive results) 48 hours Real time PCR: 24 hour	Pathfinder Mean positive median (model requires to the nearest day)
Rate of spontaneous loss of positive MRSA colonisation status in community (daily rate)	0.0027	0.0027	NHS QIS HTA [2]
Rate of loss of MRSA colonisation following decolonisation (daily rate)	0.1	0.1	NHS QIS HTA [2]
Detection rate for infected patients (daily rate)	1	1	NHS QIS HTA [2]

Parameter	NHS QIS HTA Value	Pathfinder Value	Source
Proportion of patients attending preadmission clinics within each age category	61% (Under 65s) 57% (Over 65s)	8.30% (Under 65s) 7.79 (Over 65s)	Pathfinder Project % of total number of admissions from whole data set that attended pre-admission clinic
Proportion of patients not attending preadmission clinic and going to emergency admissions ward	39% (Under 65s) 43% (Over 65s)	91.70% (Under 65s) 92.21%(Over 65s)	Pathfinder Project % of total number of admissions from whole data set that did not attend pre-admission clinic
Percentage of patients going to high-risk speciality ward	30% (Under 65s) 33% (Over 65s)	64.4% (Under 65s) 57.8%(Over 65s)	Pathfinder Project % of total number of admissions from whole data set who were admitted to a high risk specialty
Percentage of patients going to low-risk speciality ward	70% (Under 65s) 67% (Over 65s)	35.6% (Under 65s) 42.2% (Over 65s)	Pathfinder Project % of total number of admissions from whole data set who were admitted to a low risk specialty
Hospital MRSA prevalence at start of the model	3.6% (Under 65s) 14.5% (Over 65s) 7.1% Overall	2.19% (Under 65s) 5.89% (Over 65s) 5.5% Overall	Pathfinder Project % of total number of admissions who were screened positive divided by the total number of admissions who were screened
Cost of laboratory tests if result is positive (per patient)	Chromogenic agar – £7.45 Real-time PCR - £19.40	Chromogenic agar – £7.24 Real-time PCR - £27.34	Re-calculated by NHS QIS
Cost of laboratory tests if result is negative (per patient)	Chromogenic agar – £4.35 Real-time PCR - £19.40	Chromogenic agar – £4.24 Real-time PCR - £27.34	Re-calculated by NHS QIS
Decolonisation treatment per session if successful (per patient)	£9.48+ one (3) negative laboratory test	£10.80+ one (3) negative laboratory test	Re-calculated by NHS QIS
Decolonisation treatment if unsuccessful (per patient)	£9.48 + one (3) positive laboratory tests	£10.80 + one (3) positive laboratory tests	Re-calculated by NHS QIS

Table 10-9 shows the NHS QIS HTA parameters specific to tertiary referral hospitals used within the NHS QIS HTA and the parameters measured within the Pathfinder project, which were used to repopulate the model within Task 2. These values are taken from data collected in NHS Grampian only. The most significant differences are shaded in grey; these include length of stay for those without infection which are shorter than the NHS QIS HTA estimates and length of stay for those with infection which are longer than the NHS QIS HTA estimates. Costing has been updated and current analysis has increased the expected costs for isolation significantly.

Table 10-9: Parameter values specific to tertiary referral hospitals used in NHS QIS HTA and parameters collected from Grampian Health Board during the Pathfinder Project. (NHS QIS HTA Table 6-17)

Parameter	NHS QIS HTA		Pathfinder		Comments
	Value for high-risk unit	Value for low-risk unit	Value for high-risk unit	Value for low-risk unit	
Hospital discharge rate for infected patients (daily)	0.10 (Under 65s) 0.037 (Over 65s)	0.11 (Under 65s) 0.04 (Over 65s)	Computed in model using length of stay data.	Computed in model using length of stay data.	Computed in model using length of stay data.
Hospital discharge rate for colonised and non-colonised patients (daily)	0.26 (Under 65s) 0.09 (Over 65s)	0.29 (Under 65s) 0.1 (Over 65s)	Computed in model using length of stay data.	Computed in model using length of stay data.	Computed in model using length of stay data.
Rate at which colonised patients become infected during hospital stay (patients per day)	0.030	0.006	0.021 (134/6427)	0.015 (125/8123)	Number of infected admissions/sum of LOS of colonised admissions
Transmission rate, for assumed X% hospital prevalence (daily)	0.0057	0.00057	Computed in model.	Computed in model.	Computed in model.
Number of wards	15	19	15	19	NHS QIS HTA [2]values
Number of wards occupied by over 65s only	2	3	2	3	NHS QIS HTA [2]values
Number of beds per ward	25	25	25	25	NHS QIS HTA [2]values
Number of isolation single-bed rooms in ward	3	3	3	3	NHS QIS HTA [2]values

Parameter	NHS QIS HTA		Pathfinder		Comments
	Value for high-risk unit	Value for low-risk unit	Value for high-risk unit	Value for low-risk unit	
Beds within each mixed age ward that are occupied by age group	17 (under 65s) 9 (over 65s)	18 (under 65s) 8 (over 65s)	17 (under 65s) 9 (over 65s)	18 (under 65s) 8 (over 65s)	NHS QIS HTA [2]values
Length of stay per patient if patient is not infected (ie colonised) and non-colonised patients (days)	3.6(Under 65s) 8.8 (Over 65s)	3.3(Under 65s) 8.3 (Over 65s)	5.5 (Under 65s) 7.9 (Over 65s)	5.3 (Under 65s) 9.7 (Over 65s)	Calculated from Pathfinder project. mean LOS for admissions who were not infected by specialty and age group
Length of stay if patient is infected (days)	9.0 (Under 65s) 22.0 (Over 65s)	8.2 (Under 65s) 20.1 (Over 65s)	38.1 (Under 65s) 35.3 (Over 65s)	5.3 (Under 65s) 39 (Over 65s)	Calculated from Pathfinder project. Median LOS for admissions who were infected by specialty and age group
Additional cost per night of hospital stay if patient is in isolation single bed room	£50.10	£50.10	£72.76	£72.76	Re-calculated by NHS QIS
Swabbing (per patient)	£2.42	£2.42	£3.05	£3.05	Re-calculated by NHS QIS

Table 10-10 shows the NHS QIS HTA parameters specific to large general hospital used within the NHS QIS HTA and the parameters measured within the Pathfinder project, which were used to repopulate the model within Task 2. These values are taken from data collected in NHS Ayrshire and Arran only. The most significant differences are shaded in grey; these include length of stay for those without infection which are shorter than the NHS QIS HTA estimates and length of stay for those with infection which are longer than the NHS QIS HTA estimates. Costing has been updated and current analysis has increased the expected costs for isolation significantly.

Table 10-10: NHS QIS HTA table 6-18: Parameter values specific to large general hospitals referral hospitals used in NHS QIS HTA and parameters collected from Pathfinder Project. (NHS QIS HTA Table 6-18)

Parameter	NHS QIS HTA		Pathfinder		Source
	Value for high-risk unit	Value for low-risk unit	Value for high-risk unit	Value for low-risk unit	
Hospital discharge rate for infected patients (daily)	0.083	0.083	Computed in model using length of stay data.	Computed in model using length of stay data.	Computed in model using length of stay data.
Hospital discharge rate for colonised and non-colonised patients (daily)	0.208	0.232	Computed in model using length of stay data.	Computed in model using length of stay data.	Computed in model using length of stay data.
Rate at which colonised patients become infected during hospital stay (patients per day)	0.030	0.006	0.009 (73/7786)	0.007 (44/6009)	Number of infected admissions/ sum of LOS of colonised admissions
Transmission rate, for assumed 7.1% hospital prevalence (daily)	0.00677	0.00677	Computed in model.	Computed in model.	Computed in model.
Number of wards	4	10	4	10	[2] Use NHS QIS HTA values but provide actual values from Pathfinder Boards for comparison
Number of beds per ward	25	25	25	25	[2]. Use NHS QIS HTA values
Number of isolation single-bed rooms in ward	3	3	3	3	[2]. Use NHS QIS HTA values
Number of beds in open ward	22	22	22	22	[2] Use NHS QIS HTA values

Parameter	NHS QIS HTA		Pathfinder		Source
	Value for high-risk unit	Value for low-risk unit	Value for high-risk unit	Value for low-risk unit	
Length of stay per patient if patient is not infected (ie colonised) and non-colonised patients (days)	3.0(Under 65s) 8.6 (Over 65s)	2.7(Under 65s) 8.4 (Over 65s)	4.9 (Under 65s) 8.8 (Over 65s)	4.9 (Under 65s) 9.4 (Over 65s)	Calculated from Pathfinder project. mean LOS for admissions who were not infected by specialty and age group
Length of stay if patient is infected (days)	7.5(Under 65s) 21.5 (Over 65s)	6.8 (Under 65s) 21.0 (Over 65s)	42.6 (Under 65s) 40.6 (Over 65s)	19* (Under 65s) 33.5 (Over 65s) *based on two observations	Calculated from Pathfinder project. mean LOS for admissions who were infected by specialty and age group
Additional cost per night of hospital stay if patient is in isolation single bed room	£59.15	£59.15	£84.05	£84.05	Economist help required
Swabbing (per patient)	£2.55	£2.55	£3.20	£3.20	Economist help required Should be re-worked for current costing

Table 10-11 shows the sensitivity analysis undertaken within the NHS QIS HTA. The final column indicates which scenario was found within the pathfinder study in order to indicate the potential effect on the model the findings would have. For example when the model was adjusted to show that Single rooms were occupied prior to introduction of screening (as was true within the Pathfinder hospitals), the effect was that prevalence of colonisation after one year was 2.05%, costs increased to nearly six million pounds and the number of infections was 149.5 which is even greater than was found in the Grampian within the year (135 infections)

Table 10-11: NHS QIS HTA Table 6-25 Summary of results of sensitivity analysis- assumed large tertiary referral hospital i.e. Aberdeen Royal Infirmary

	MRSA prevalence after one year (%)	Costs of screening	Number of infections	Observed during Pathfinder
Base case Strategy 2 ChromChrom	0.359	£1,223,289	65	Predicted
Pathfinder	3.14	£1,600,000 (includes start-up costs not included in model)	135	Observed
Sensitivity analyses				
One isolation bed in low-risk wards, two in emergency admission and high-risk wards	0.782	£1,217,951	91.1	×
One isolation bed in low-risk wards, two in emergency admission and high-risk wards no decolonisation	1.054	£1,205,257	106.3	×
One isolation bed in each ward	1.605	£1,207,337	132.6	✓?
Initial overall prevalence of MRSA colonisation 3.6%	0.100	£1,108,886	25.6	✓
Initial overall prevalence of MRSA colonisation 14.5%	2.015	£1,460,085	177.6	×
50% effectiveness of isolation to reduce transmission	2.583	£1,343,075	158.3	✓?
50% effectiveness of isolation to reduce transmission; no decolonisation	2.552	£1,314,260	159.5	×
Sensitivity of chromogenic agar test 95%, and false-positive rate 2%	0.422	£1,672,159	69.4	?
Mean length of stay increased by one day	0.411	£1,211,057	72.4	×

	MRSA prevalence after one year (%)	Costs of screening	Number of infections	Observed during Pathfinder
Mean length of stay decreased by one day	0.614	£1,272,226	82.9	✓
Single rooms occupied prior to introduction of screening	2.050	£5,830,328	149.5	✓

Given that a large number of the factors within the sensitivity analyses which profoundly affected the model were observed within the Pathfinder project and the large number of the assumptions which were not supported by the findings, the original model was adapted and re-populated with the parameter estimates derived from the pathfinder project.

The model was then adjusted to include the changes described within the methodology section. This allowed the model to operate in a way which was more representative of the observations found within the Pathfinder project. The parameters collected within the Pathfinder study were then included within the model and the following results produced.

The following results were produced by the re-worked model. Within this model Strategy 1 (which involved no screening, but isolation and treatment of patients who were identified with MRSA infection) set as a baseline. This decision was made with consultation with the Technical and Programme Board who agreed that Strategy 1 represented an idealised picture of current practise within NHS Scotland. This is not directly comparable with the HTA as the do nothing strategy within the HTA would have produced a fixed prevalence on admission which would equal the starting prevalence. Figure 10-1 and Figure 10-2 shows the comparative prevalence of each strategy over a period of five years given the starting prevalence of 5.5% of admissions being MRSA colonised in tertiary referral hospital and a large general hospital. Figure 10-1 shows a decline over five years in prevalence on admission of 5.5% to 1.8% with strategy one and 0.4% with strategy 2 for ChromChrom and 0.8% for ChromPCR.

Figure 10-1: Change in percentage prevalence over time for Strategy 1 (no screening) set as a baseline compared with Strategy 2 for ChromChrom and Chrom PCR for tertiary referral hospital and Pathfinder data for year one (NHS QIS HTA Figure 6-3) with a starting MRSA colonisation prevalence of 5.5%

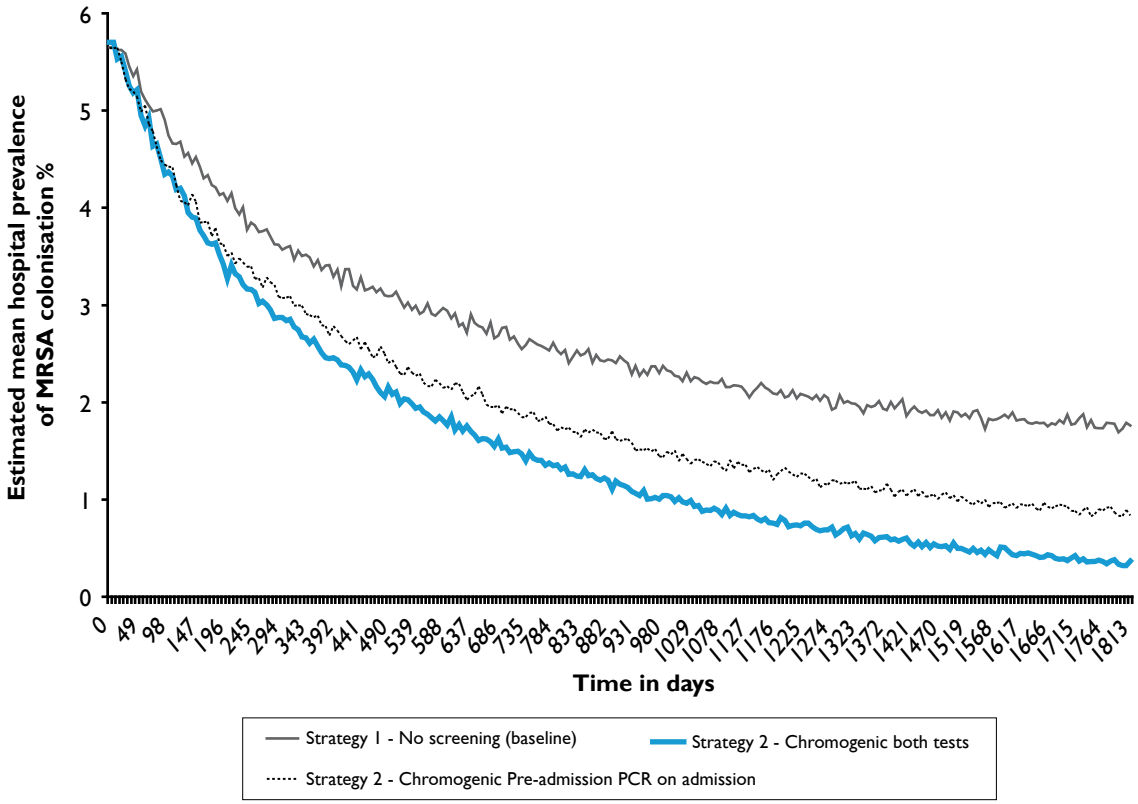
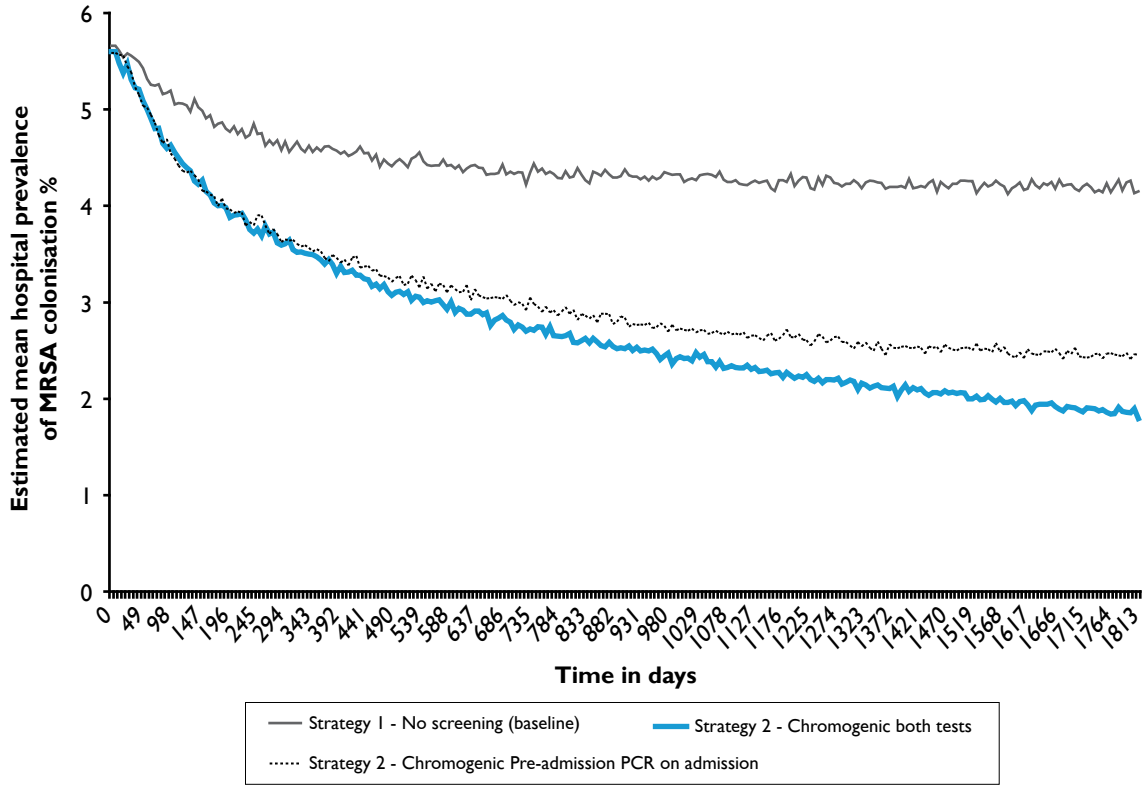


Figure 10-2 shows a slightly different effect within large general hospitals of implementation of screening (whether the test is chromogenic agar in all cases or chromogenic for electives and PCR for emergencies). In fact within the model the PCR option shows a slightly smaller reduction than chromogenic agar, this is due to the small increase in false positives with PCR. Both strategies initially identify more patients who are colonised with MRSA than can be isolated. Within large general hospitals the prevalence on admission is projected within one year of implementation to be reduced to 3.5% of admissions compared with 4.6% of admissions with no screening intervention. Over the five years projected within the model the no screening strategy 1 shows a fixed prevalence of around 4.1% where chromogenic agar for both tests reduces MRSA colonisation prevalence to 1.8% of admissions within five years (see Table 10-17).

Figure 10-2: Change in percentage prevalence over time for Strategy 1 (no screening set as a baseline) compared with Strategy 2 for ChromChrom and Chrom PCR for large general hospital (NHS QIS HTA Figure 6-3) With a starting MRSA colonisation prevalence of 5.5%



The number of infections estimated to be seen in each year using each of the three screening approaches within a tertiary referral hospital are summarised on Table 10-12. It can be seen that in year one with no screening an estimated 681 infections would be expected within the first year of screening. In strategy two using Chromogenic agar test throughout 437 infections would be expected. It must be remembered that this is a theoretical hospital based on an average tertiary referral and no attempt was made to model exactly the hospitals within the Pathfinder study. This is the approach used in the Pathfinder study, during the year of the study in Grampian health board Pathfinder hospitals 135 infections were recorded according to the CDC case definitions used. It is important to recognise that the model does not take into account the effect of any other hospital infection control interventions.

Table 10-12: MRSA infections predicted each year from each strategy for tertiary referral hospital

Year	Strategy 1 – no swab			Strategy 2 - ChromChrom			Strategy 2 - ChromPCR		
	Number of infections	95% CI		Number of infections	95% CI		Number of infections	95% CI	
	n	Lower	Upper	n	Lower	Upper	n	Lower	Upper
0	1,109	1,010	1,208	1,111	1,011	1,212	1,113	1,015	1,210
1	681	593	770	437	348	526	473	385	562
2	480	394	565	204	133	275	274	187	361
3	398	312	484	123	54	191	198	112	283
4	348	260	436	75	11	139	156	72	240
5	319	228	410	47	0	105	126	40	211
Total infections over five years of implementation	**2,226**			**885**			**1,227**		

The number of infections estimated to be seen in each year using each of the three screening approaches within a large general hospital are summarised on Table 10-13. It can be seen that in year one with no screening an estimated 124 infections would be expected within the first year of screening. In strategy two using Chromogenic agar test throughout 78 infections would be expected. Overall using strategy 2 the model projects that the total number of infections seen will be 277 compared with 575 with Strategy one set as the baseline. This would be a reduction of over half the infections within five years.

Table 10-13: MRSA infections predicted each year from each strategy for large general hospital with Strategy 1 as the baseline

Year	Strategy 1 – no swab			Strategy 2 - ChromChrom			Strategy 2 - ChromPCR		
	Number of infections	95% CI		Number of infections	95% CI		Number of infections	95% CI	
	n	Lower	Upper	n	Lower	Upper	n	Lower	Upper
0	149	122	177	149	123	175	150	124	176
1	124	99	148	78	51	106	80	52	107
2	114	89	139	60	27	93	64	35	94
3	113	88	138	52	16	88	59	28	91
4	112	86	137	46	8	84	56	23	90
5	112	86	137	41	1	82	54	19	90
Total infections over 5 years of implementation	**575**			**277**			**313**		

Table 10-14 shows the effect of implementing screening in a tertiary referral hospital (with either Chromogenic agar for all tests or chromogenic agar and PCR for emergency admissions) compared with the baseline of no screening is 1,341 over five years from chromogenic agar only and 999 for Chromogenic agar and PCR in a tertiary referral hospital.

Table 10-14: Number of infections prevented each year from each strategy for tertiary referral hospital

Year	Infections prevented		
	Strategy 1	Strategy 2	Strategy 2
	No screening	ChromChrom	ChromPCR
0	0	0	0
1	0	244	208
2	0	276	205
3	0	275	200
4	0	273	192
5	0	272	194
Overall	**0**	**1,341**	**999**

Table 10-15 shows the effect of implementing screening in a large general hospital compared with the baseline of no screening is 296 over five years from chromogenic agar only and 260 for chromogenic agar and PCR in a large general hospital.

Table 10-15: Number of infections prevented each year from each strategy for large general hospital

Year	Projected infections prevented		
	Strategy 1	Strategy 2	Strategy 2
	No screening	ChromChrom	ChromPCR
0	0	0	0
1	0	45	44
2	0	54	50
3	0	61	53
4	0	66	55
5	0	70	57
Overall	**0**	**296**	**260**

Table 10-16 summarises the effect on costs, prevalence of colonisation and infection for each of the three strategies within a tertiary referral hospital. It is important to note that the cost is a combination of additional costs of implementing the screening programme and the opportunity cost of isolating the patients identified as colonised or infected with MRSA. It is important to consider that the cost of staffing isolation rooms is included within hospital budgets without the implementation of an MRSA screening programme. The model shows that PCR would be more than twice as costly as chromogenic agar screening with no additional reduction in infections within a five year period. Both strategies where screening in undertaken show a reduction of colonisation to 0.4% of admissions being colonised from ChromChrom and 0.8% of admissions being colonised for ChromPCR compared with the no screening option where 1.8% of admission would be positive.

Table 10-16: Summary of results for a tertiary referral hospital using Strategy 1 and Strategy 2 using ChromChrom and ChromPCR (Table 6-23 in NHS QIS HTA)

Year	Strategy 1 No screening			Strategy 2 ChromChrom			Strategy 2 ChromPCR		
	Prevalence	Total Cost	N infections	Prevalence	Total Cost	N infections	Prevalence	Total Cost	N infections
0	5.5	£0	1,109	5.7	£0	1,111	5.7	£0	1,113
1	3.4	£1,339,800	681	2.6	£1,496,600	437	2.9	£2,442,300	473
2	2.6	£1,085,500	480	1.5	£1,009,100	204	1.9	£2,172,700	274
3	2.2	£923,360	398	0.8	£730,790	123	1.3	£2,012,600	198
4	1.9	£818,690	348	0.6	£546,540	75	1.0	£1,910,300	156
5	1.8	£757,180	319	0.4	£431,710	47	0.8	£1,836,900	126
		£4,924,530			**£4,214,740**			**£10,374,800**	

Table 10-17 summarises the effect on costs, prevalence of colonisation and infection for each of the three strategies within a large general hospital. The model shows that PCR would be twice as costly as chromogenic agar screening with no additional reduction in MRSA infection (see Table 10-14). The variation from hospital type will be due to variation in length of stay and specialty mix. Both strategies where screening is used show a marked reduction in colonisation and infection compared with the no screening option where over five years the colonisation prevalence reduced to 4.1% compared with Strategy 2 ChromChrom where colonisation prevalence after five years was reduced to 1.8% and ChromPCR where colonisation prevalence after five years was reduced to 2.5%.

Table 10-17: Summary of results for a large general hospital using Strategy 1 and Strategy 2 using ChromChrom and ChromPCR (Table 6-24 in NHS QIS HTA)

Year	Strategy 1 No screening			Strategy 2 ChromChrom			Strategy 2 ChromPCR		
	Prevalence %	Total Cost	N infections	Prevalence %	Total Cost	N infections	Prevalence %	Total Cost	N infections
0	5.6	£0	149	5.6	£0	149	5.5	£0	150
1	4.6	£292,680	124	3.5	£416,230	78	3.6	£751,920	80
2	4.3	£295,040	114	2.7	£365,520	60	3.0	£723,710	64
3	4.2	£291,720	113	2.3	£331,410	52	2.7	£706,780	59
4	4.3	£290,730	112	2.1	£306,500	46	2.5	£696,040	56
5	4.1	£289,220	112	1.8	£285,310	41	2.5	£690,760	54
		£1,459,390			**£1,704,970**			**£3,569,210**	

11 Discussion

11.1.1 Aim 2 Objective 1: To identify the proportion of patients admitted electively who attend pre-assessment clinics and the proportion that were screened and the reasons for not screening

During the pathfinder study period around a third of patient admissions were admitted electively, but only about a quarter of those admissions attended a pre-admission clinic. Nonetheless most (98%) of those who did attend a preadmission clinic were screened. It is acknowledged that not all patients admitted electively will attend a pre-admission clinic and as such many will require to be screened on admission. For example, within Grampian health board only 14.0% of elective admissions attended a pre-admission clinic however, of those attending pre-admission clinics, 99% were screened. Uptake varied by the specialty of the preadmission clinic and was highest in surgery (98%) and lowest in oncology (91%). The pathfinder project showed that uptake of screening within pre-admission clinics can be successfully implemented and a high compliance achieved within this environment. The main issue is that many areas do not run pre-admission clinics, especially those hospitals which serve a geographically dispersed population.

The best predictor of patient admissions being screened at pre-admission was hospital and specialty; this is to be expected as certain specialities run pre-admission clinics and others do not. Ayr and Crosshouse hospitals run more pre-admission clinics with 30.3% of elective patient admissions attending pre-admission at Ayr Hospital and 28.6% of elective patient admissions at Crosshouse Hospital. The HTA model assumed that 100% of elective admissions were screened and their results returned before they arrived at hospital. It further assumed that the patient admissions that were found positive as a result of a pre-admission screen were known before they attended hospital and therefore it was possible to begin decolonisation before they undergo their hospital treatment. Ideally these patients would be decolonised before admission to minimise the risk of infection during their stay.

In the pathfinder study, just over two percent of patients screened at preadmission clinics were found to be colonised with MRSA and this represents 0.2 percent of all admissions. In order to decolonise these admissions considerable healthcare resource is required, and effort from the patient to collect their decolonisation pack, and then return for repeat screens. The small proportion of acute care admission patients this was achieved in calls into question the value of screening pre-admission utilising patient care pathways already in place for another purpose. There may be merit in redesigning the preadmission screening process to enable it to be more effective and efficient.

Key summary point

Although only one quarter of elective admissions attend pre-admission clinics, those who do attend can be effectively screened with 98% overall of those attending pre-admission clinics being screened.

11.1.2 Aim 2 Objective 2: To identify the proportion of emergency admission and specialty transfer (between hospitals) patients who were screened on admission.

During the pathfinder project 70% of all patient admissions were admitted as emergency cases. Of those 85% were screened on admission. Of those screened 4.5% were found to be MRSA colonised. This is significantly higher than the percentage of elective admissions found to be positive (2.1%).

The variables which best predicted being screened on admission were length of stay, month of admission, specialty, hospital, and whether admitted from home or not. Patients with lengths of stay over eight night's were four times more likely to be screened than those with only one nights stay. No study was identified in the published literature (reviewed for this report) which had examined the reasons for patient not being screened and these results are of interest in designing ways to improve the process for screening.

Compliance within the pathfinder boards varied over the study period. The results indicated that the last quarter of the year of data collection had higher uptake rates and indicated that as the universal screening process embedded into practice, the uptake improved. As stated earlier these data are based on the data collected during the Pathfinder study, it is likely that compliance with screening was higher than reported. This does however compare favourably to the UK study by Rao [28] who found overall compliance to be 56.4% during the year of implementing universal MRSA screening in a single hospital. The maximum monthly compliance was in Western Isles with a maximum monthly compliance 99%. Rao found a maximum monthly compliance to be 89.1%. Throughout the project the pathfinder boards monitored compliance and implemented new techniques to improve compliance. Improvement is shown in the MRSA Screening Programme Clinical Effectiveness Report [3] where the odds of being screened are shown to increase with each quarter (three month period).

There are two separate issues which contribute to the reduced compliance: identifying newly admitted patients and screening of short stay patients i.e. patients were not identified and screened before they are discharged. A new patient in some instances was not entered into the patient management system until the day after they have been admitted. Therefore, if a screening team is employed it can be very difficult to remotely identify when a new eligible patient has been admitted.

In Grampian a number of approaches were implemented to ensure new patients were screened and identified; screening team members checked patient management systems, bed management systems and health intelligence data, and were given pagers and ward staff asked to page a screener when a new patient was admitted. Compliance varied throughout the hospital; in some specialties it was excellent however there were areas which required continuous improvement.

In Ayrshire and Arran there were issues around staff identifying patients who required a screen. There was an initial assumption by some ward staff that patients were screened in Accident and Emergency and few checks were undertaken at ward level to ensure that patients had been screened. This was resolved by stopping screening in Accident and

Emergency and informing all wards to screen patients who are admitted through Accident and Emergency. As a result compliance improved. The main reason patients were not being screened was that they were missed, i.e. discharged before they had an opportunity to be screened. These were patients admitted for less than 24 hours. There was deemed to be little advantage in pursuing these patients as their results would not be available before discharge and there would therefore be no opportunity for intervention during their stay to minimise the risk of infection.

Key summary point

Compliance within the study period was found to be 85% based on forms returned, while this is less than the 100% described within the NHS QIS HTA, it compares favourably to the published literature. The main reason for patients not being screened is that they were discharged before the screen was taken.

11.1.3 Aim 2 Objective 3: To monitor the turnaround time (TAT) for reporting from sample collection to reporting by laboratories and where the potential delays are.

A key issue regarding the organisation of the screening programme was that the results of admission screens took between 26 to 70 hours for a positive result (24 to 42 hours for a negative result). The turn around times varied from board to board and reflected the nature of the size of a hospital and shift patterns of the laboratory staff. Positive samples had a longer median turn around time on average of 48 hours, compared to 28 hours on average for negative results.

The factors affecting turn around time were: type of admission, hospital, time swab was taken, day swab was taken and the result of the admission screen. Those patients admitted as emergencies, out of hours and at weekends had longer turn around times for tests than those electives admitted in office hours on weekdays.

Grampian's laboratory were able to analyse samples over a longer working day and over weekends, where the other pathfinder boards have smaller laboratories which were only able to undertake a single run of overnight samples. Grampian had also adopted a procedure where presumptive MRSA positive results were phoned to the wards in order to enable early isolation or cohorting, i.e., they do not wait until these samples have been fully confirmed by the laboratory to inform the clinical staff. It is important to acknowledge that some of the very long turn around times are due to the laboratory information management systems (LIMS), the time of finalising the result was the time that was recorded by data collectors and within Grampian any results that have not been finalised are reviewed on a weekly basis, this may account for long turn around times within the negative and positive results. Results are reported in a timely manner but a proportion of those results are delayed in being finalised within the LIMS. Some positive results are not finalised according to the laboratory system until they have been sent to the Reference Laboratory and their finding reported back.

Laboratory processes are critical in determining turn around time, nonetheless the process between the sample being taken and it getting to the laboratory is also important. The median times for samples to get to the laboratories varied by pathfinder board (1 - 6 hours). This time is a rate limiting step in terms of reducing overall turnaround time, even with the emergence of new technologies. Those technologies which are focussed on near patient testing may be able to reduce overall turn round time more effectively than those which are laboratory focussed.

The NHS QIS HTA estimated that the turnaround time for swab results was 24 hours for all results; no distinction was made between TAT for negative and positive screen tests. Most positive results took considerably longer for turn around time (TAT) than this estimate. The model required known positives to be isolated and decolonised at the earliest opportunity. Within the model it was assumed that all elective admissions test results were known on admission and that emergency admission were admitted to receiving units. It was also assumed that these patients did not leave that unit until they had received their MRSA screening result. As a result no patient would be admitted to a specialty ward with MRSA status unknown. Whilst this would be an ideal scenario, the findings in the pathfinder study indicated it was far from the reality of patient pathways within the NHS.

The model also assumed that patients were screened on admission, there was a short delay which added to the time the patients MRSA status was unknown this ranged from one to six hours within the Pathfinder health boards.

Key summary point

Median turn around time for positive samples within the study was 48 hours and 27 hours for negative samples. The NHS QIS HTA model used a single parameter for negative and positive tests of 24 hours. Turn around time was affected by type of admission, hospital time and date swab was taken and the result of the screen test. Time to screen added to turn around time gives the total length of time for a patients MRSA status to be reported within the hospital.

11.1.4 Aim 2 Objective 4: To identify the proportion of patients with a positive MRSA screen identified at a pre-assessment clinic who were not subsequently admitted as planned.

Fourteen patients were recorded as having a deferred procedure due to a MRSA positive screen. This represented around ten percent of all MRSA positive results identified at the preadmission screening. This issue is considered to be important for patient acceptability, but the data from the pathfinder suggest it affected a very small proportion (0.02%) of admissions to acute care in a year.

The decision to defer an admission is a matter for the consultant caring for the patient and is made with a balance of urgency of the patient's admission versus the risk of MRSA infection from that procedure. It is important to consider that without MRSA screening these patients would be admitted and their procedures undertaken without the clinical team knowing their MRSA status. As such this is not seen as a risk associated with the MRSA screening programme.

Key summary point

A very small proportion of admissions were recorded as having been delayed as a result of their MRSA colonisation.

11.1.5 Aim 2 Objective 5: To identify the proportion of patients screened for MRSA who were admitted to high-risk and low-risk specialty wards

Two thirds of admissions in the pathfinder year were to high risk specialties and a third to low risk. Admissions screened preadmission were more likely to be admitted to high risk specialties. The NHS QIS HTA estimated that a lower proportion (30%) of those under and over 65 years would be admitted to high risk specialties, whereas the results here indicated the proportion was almost double this. For low risk specialties the proportions of patients were found to be lower than that assumed for the model.

The NHS QIS HTA Strategy 2 assumed patients in high risk specialties to be isolated or cohorted and decolonised, but low risk patients only isolated or cohorted. This was initially attempted in NHS Ayrshire and Arran. The Central Legal Office (CLO), in discussion with HPS, approved the mixed approach as there was no standardised approach for decolonisation of patients currently, and on that basis each board was attempting to reduce cross transmission of colonisation and infection with MRSA.

Patient movement made the NHS QIS HTA strategy 2 very difficult to implement in Ayrshire and Arran. For example patients who were admitted to general medicine, underwent a range of tests and were eventually admitted to a high risk specialty like cardiology. The infection control team assessed this situation and decided that these patients were not being given the opportunity to be decolonised at a time which would have reduced the risk when moved to a higher risk specialty. It was also deemed unfeasible to treat high and low risk speciality patients differently.

Patient movement throughout the hospital resulted in patients being cared for under the same low risk specialty but being treated differently with regards to decolonisation as a result of their route through the hospital. An exception report was raised and presented to the Programme board, based on the report from Ayrshire and Arran and some analysis of interim results. It was agreed that the best approach was to revert to a strategy of decolonising all colonised patients regardless of specialty.

Current guidance on MRSA management within hospital divides patients into high risk of infection and low risk of infection [5]. In fact there was no difference in the proportion of admissions with MRSA infection within high and low risk specialties (both showed 0.2% of patients within high risk and low risk categories to have MRSA infection).

Colonisation was in fact higher within the specialties categorised as low risk with the proportion of admissions to low risk specialties with MRSA colonisation being 4.2% compared with 2.8% in high risk. The HTA expressed the number of patients admitted to high risk and low risk as a proportion of admissions over and under 65 years of age. The HTA estimated around one third of both under and over 65s admissions to be to a high risk specialty and two thirds to be to a low risk specialty. Within the pathfinder project this was found to be the reverse i.e. two thirds of both under and over 65s admissions to be to a high risk specialty and one third were admitted to a low risk specialty. This finding had a significant effect on the performance of the model.

Key summary point

Within the pathfinder project two thirds of both under and over 65s admissions were admitted to high risk specialties and one third were admitted to low risk specialties. This was significantly different to the NHS QIS model estimates as is the fact that no difference was found in incidence of infection in high risk or low risk specialty admissions and prevalence of colonisation on admission was found to be higher within low risk specialties.

11.1.6 Aim 2 Objective 6: To evaluate the proportion of those patients pre - emptively isolated who subsequently were identified as MRSA positive.

The HTA model assumed that all patients who were admitted electively and found to be positive would be admitted to an isolation room. It also assumed that the emergency admissions would be admitted to an emergency receiving unit on admission and remain there for a minimum of 48 hours within which time they would receive the result of their MRSA test and therefore no unknown MRSA status patients would be admitted to a specialty ward. In fact patient movement within the pathfinder project was a significant barrier to implementation of strategy 2 from the NHS QIS HTA model. Often elective admissions were not screened until they were admitted. The protocol of the study suggested that patients with previously know positive MRSA status should be isolated until their test result was available.

Of the admissions (without a pre-admission test result), who were admitted to isolation on day one of their admission, just over 70% were subsequently confirmed to be MRSA positive. This indicates that the clinical criteria by which patient admissions were identified as "potentially MRSA positive" were relatively successful. Although clinical risk assessment was considered to be less accurate and more expensive than laboratory testing by the HTA review of the evidence, it does have the advantage that it is possible to take action on day one of admission without awaiting the test results.

A small proportion (10%) of all previously known positives were pre-emptively isolated according to the protocol (n=529 of 4964) were isolated on day one of their admission). This indicates that clinical risk assessment had a large part to play in allocating patients on admission to isolation. Nonetheless most laboratory confirmed positive admissions were nursed on the open ward to the point of the laboratory confirmation test being reported back, as they were not known to be positive at the time. This finding reinforces the importance of the continued role of clinical risk assessment on admission in order to minimise risk of infection.

Key summary point

Overall 70% of the admissions without a pre-admission test result, who were admitted to isolation on day one of their admission, were subsequently confirmed to be MRSA positive, indicating that clinical risk assessment has a part to play in allocating patients to isolation.

11.1.7 Aim 2 Objective 7: To evaluate the proportion of MRSA positive patients who receive decolonisation treatment.

Overall 45% of all positive admissions underwent some decolonisation therapy. Factors accounting for this were investigated and length of stay was an independent predictor of whether someone received decolonisation therapy. Less than ten percent of those patients with lengths of stay of a day were commenced on decolonisation therapy whereas almost two thirds of those admitted for two nights or more received the therapy. Results did vary by board but less so when length of stay was accounted for.

For those attending preadmission clinics, 48% of those screened as positive received decolonisation therapy and 13% of those had three negative screens prior to admission. For those being screened at the point of admission to hospital, 44% (of those screening positive) received decolonisation treatment and only seven percent of those found positive who received decolonisation were successfully decolonised during their stay i.e. received three negative post decolonisation tests prior to discharge (this equates to three percent of all those found positive on admission). This was due, as indicated previously within the discussion, to short lengths of stay.

Key summary point

Less than half of the admissions found to be positive were initiated on decolonisation. Three percent of admissions found positive during their stay, were successfully decolonised. This was however largely due to length of stay and patients being discharged before decolonisation could be completed.

11.1.8 Aim 2 Objective 8: To evaluate the distribution of patient length of stay by specialty i.e. who can be screened and treated.

Factors influencing length of stay within the pathfinder project included age and speciality of admission. Overall a quarter of patients were in hospital for one day (including an overnight stay). Those patients in specialties with longer lengths of stay, such as: dermatology, anaesthesia, stroke, ICU, cardiac surgery, which all had average lengths of stay of around 10 days, were therefore more likely to have the interventions associated with the screening programme.

The majority (75%) of admissions in the study were discharged within eight days of admission. All of these admissions were discharged before completion of their decolonisation therapy. Specialties with the longest lengths of stay had the highest uptake of screening.

Length of stay must be considered by MRSA status in order to consider numbers of patients who could possibly have the interventions associated with the screening programme (decolonisation and isolation during the hospital stay). Of those patients who screened positive and were in hospital more than two days, almost 70% commenced decolonisation therapy compared with only 8% of those in less than two days. Those who were in hospital for more than eight days represented 43% of all positive screens and 42.5% of all those isolated. A large proportion of these patients (64.2%) were isolated or cohorted during their stay. Therefore specialties with the longest average length of stay are able to successfully intervene as a result of the screening result.

Key summary point

Median length of stay in the study was three days overall, and depending on health board, specialties with a longer length of stay are better placed to undertake the interventions of decolonisation and isolation.

11.1.9 Aim 2 Objective 9: To describe the number of single bed rooms available per ward

The NHS QIS HTA assumed there were three isolation rooms per 25 bed ward [2]. There were no data available on how many of those beds would be available for isolation of MRSA patients, therefore in the absence of any other data the assumption was made that the three isolation rooms were available for MRSA colonised patients. At the time the NHS QIS HTA was written, on average 20% of beds were single rooms in NHSScotland.

In the pathfinder boards there are more than three single rooms per 25 bed ward. On average there were between 4.5 (Ayrshire and Arran and Grampian) to 5 (Western Isles) per ward. However these rooms were not available at all times for patients with MRSA. Within the pathfinder boards the reality was that 7.7% of admissions required isolation due to MRSA at some time during their stay. However, availability of isolation rooms varies from

specialty to specialty as did MRSA colonisation prevalence. For example in specialties like general medicine and general surgery, where there was a high volume of patients who were MRSA colonised, the availability of isolation facilities was not proportionate to this number of colonised patients.

The decision making process for the allocation of single rooms is a complex one based on a number of factors, as described. The criteria for allocation of a single room is summarised in the HPS transmission based precautions [29] with regards to infection control, but there are many other issues which influence this including severity of the patient's illness and other types of infection. Availability of isolation rooms is a critical intervention associated with the screening programme. There is little point in screening patients if the intervention associated with the result cannot be implemented. SGHD has a policy commitment for NHSScotland to increase the proportion of single rooms in an ongoing programme over the next five years [30]. As this programme develops, more availability of single rooms will enable more patients to be placed as required.

Key summary point

Almost eight percent of admissions required isolation due to MRSA at some time during their stay. Availability of isolation rooms varies from specialty to specialty, as did MRSA colonisation prevalence however availability of isolation facilities does not necessarily reflect this requirement.

11.1.10 Aim 2 Objective 10: To evaluate the proportion of patients identified as colonised who are isolated, cohorted or separated

As indicated above, the number of isolation rooms overall in each ward was found to be greater than the three outlined in the assumptions in the NHS QIS HTA. However these rooms were not always available for MRSA isolation and these are required for a number of reasons not just MRSA isolation e.g. for privacy at the end of their life or due to infections other than MRSA. During the year of the pathfinder project, just under half (47%) of those patients screening positive were isolated at some point during their stay. Factors which independently predicted isolation were the hospital (and its isolation facility availability), length of stay and frequency of readmission.

Admissions staying in hospital for four or more nights were 2.5 times more likely to be isolated than those staying for one night. Those patients staying in hospital for more than eight nights accounted for almost half of positive admission screens and almost all of these patients (92%) were isolated or cohorted during their stay. It should be noted that many patients were not in hospital long enough to receive their laboratory results and therefore were unable to be isolated during their stay as their MRSA colonisation status was not known until they were discharged.

As indicated previously, where isolation was not possible, cohorting or separation was undertaken. The NHS QIS HTA model used isolation as the intervention to prevent cross transmission of MRSA as there is some evidence for this working as an intervention to prevent cross transmission of infection[1]. In practice within the pathfinder boards, and the wider NHS, cohorting was used to nurse MRSA patients due to a lack of adequate facilities. There is less evidence for this practice in terms of its ability to reduce cross transmission of infection.

The NHS QIS HTA [2] outlined the following options for accommodating patients with MRSA colonisation or infection in order of the evidence underpinning them:

1. Isolation rooms with anterooms as a preferred option
2. Standard single rooms assuming use of standard infection prevention and control precautions (SIPC)
3. Cohorting of patients colonised or infected with MRSA being cared for by dedicated staff (staff cohorting)
4. Cohorting of patients colonised or infected with MRSA (patient cohorting)
5. Separation of patients with use of standard and contact precautions in an open ward setting.

Patient cohorting was the most common approach in which patients with similar MRSA status were nursed in a side room or bay by staff who also nurse patients on the main ward. In both cases contact precautions were used. If patients were isolated at all times then false positive patients would be at no increased risk of colonisation or infection. However, cohorting means that any patient identified incorrectly as MRSA positive (due to the positive predictive value of the chromogenic agar test) may be exposed to MRSA cross colonisation unnecessarily.

Key summary point

During the year of the pathfinder project, just under half of those patients screening positive were isolated at some point during their stay. Short lengths of stay and turnaround time of the test have a impact on ability to isolate as well as availability of facilities.

11.1.11 Aim 2 Objective 11: To describe the reasons for not isolating colonised patients

The majority of patients with MRSA left isolation during the pathfinder project due to discharge (92.4%) the need for patients to be observed (1.5%) or the room becoming unavailable. However many patients who were not isolated or cohorted because they were in hospital for less then two days and therefore their MRSA colonisation status was not known until discharge.

The slow turn around time of the test and short length of stay presents a real challenge for managing patients during their stay to reduce the risk of infection. Those patients who were MRSA colonised and in specialties with longer average lengths of stay, were more likely to be isolated.

Only two MRSA positive admissions out of 1,011 exited isolation during their stay as a result of having three negative screens post decolonisation therapy.

Key summary point

Many patients who were not isolated or cohorted because they were in hospital for less then two days and therefore their MRSA colonisation status was not known until discharge.

11.1.12 Aim 2 Objective 12: To evaluate the proportion of patients identified as colonised and not decolonised and the reasons for this

Overall 55% of those patients identified as colonised were not commenced on decolonisation treatment. The factor mainly influencing this was again length of stay, in the same way described above for use of isolation. Of those admissions that were not initiated on decolonisation 84.8% of them were discharged or died before their results were returned. Those patients in hospital for two days or more were eight times more likely to be decolonised. Almost 70% of those staying more that 2 days commenced on decolonisation treatment, compared with less than 10% of those in for less than two days. Aside from the barrier of short length stay other reasons for not commencing decolonisation treatment were predominantly for clinical decision reasons.

Key summary point

Of those admissions that were not initiated on decolonisation the majority, (84.8 %) of them were discharged before their results were returned.

11.1.13 Aim 2 Objective 13: To describe the reasons why all inpatient admissions were not screened

Uptake of screening by patients who were offered it was high (99.96% of all admissions). Around 15% of all potential admission screens were not achieved during the pathfinder project. Most (97.4%) of these were missed opportunities for screening admissions due to short duration of stay (three days or less). Compliance with universal screening is therefore more difficult to achieve in those patients with short lengths of stay. The reasons for not screening patients also included: clinical conditions and existing therapies, nasal trauma and devices, lab request errors. Only 35 patient refusals were recorded, representing a very small proportion (0.03%) of all patient admissions.

Key summary point

Uptake of screening by patients who were offered it was high. Fifteen percent of potential admission screens were not undertaken most of these were missed opportunities due to short duration of stay.

11.1.14 Aim 2 Objective 14: To identify new technologies

New technologies continue to emerge in the field of diagnostics for MRSA screening, in recognition of the requirement for diagnostic accuracy and speed of return of the result. The criteria for adoption of new technologies in healthcare should be scientifically justifiable to both clinicians and the public [4;31] and involves balancing the sensitivity and specificity of the test with the costs. It is also important to identify technologies and methods which can be demonstrated to be effective in reducing hospital infection rates.

This pathfinder project has demonstrated that the long turn around time for results (average 48 hours) together with a short length of stay (average three days) for patients in acute care means that there is little opportunity for intervention during the hospital stay for most patients. These findings indicate that that there is a need for quicker turn around of results in order to reduce risk of infection during the hospital stay. In recognition of this issue, there is considerable literature emerging on the use of "rapid tests" for the identification of MRSA.

Three recent reviews in key journals clearly indicate that this area is currently of high interest clinically [31-33]. From a review of these and other available literature there are two main methods being used and evaluated for the rapid identification of MRSA; selective agars (e.g. chromogenic agars) and polymerase chain reaction (PCR) [32;33]. Both these methods have advantages and disadvantages. The principle drawback of selective agars is a long turnaround time for results of up to 72 hours [33-35].

PCR is a very quick and effective method that has been developed to detect the presence of MRSA looking for genetic elements (e.g. mecA and orfX) on the staphylococcal cassette chromosome mec (SCCmec) [31;33]. PCR achieves high sensitivities and specificities in most cases [31;33;34;36-50]; however some commercially available tests have been found not to detect certain variants of MRSA [32;33;51]. The rapid turnaround times achieved with PCR in the laboratory mean that a negative result can be available within four hours, [32-34;36;43;50] and one assay can produce a result in 75 minutes [32;33;49;52]. However the pathfinder project has demonstrated, in line with previous studies [32;37;39], that turnaround time of results is constrained by organisational factors in the laboratory and wider hospital such as the ability to screen close to admission time, portering services and systems for getting results back to the ward and appropriate clinician to ensure they are acted upon.

One assay has been highlighted as being applicable for "near patient testing" or "point of care" with the potential for quicker confirmation of negative results [52]. Although some literature has identified that even with near patient testing, ensuring the interventions associated with the positive results are quickly implemented remains a challenge as infection control resources can also be a limiting factor [5;31;53;54]. Rapid molecular tests for MRSA screening are only useful if that can be combined with adequate infection control measures.

PCR detects the presence of genes associated with MRSA but positive results may require further culture [32;33] and to determine sensitivity profiles particularly for mupirocin. It has been noted in the literature that potential benefits to patients of rapid screening tests has not been fully assessed [31-33;35;55]. The latest systematic review [31], published in the Lancet this year, supports the concept of MRSA screening programmes, however notes that the evidence for using molecular tests is of insufficient quality at present to fully support the use of these tests, if a culture based screening programme already exists.

There is a lack of evidence regarding the effectiveness of these rapid tests in reducing transmission of MRSA, it can however be concluded that they have the potential to allow for more effective patient management by reducing the length of unnecessary isolation for patients pending test results with all the attendant problems [32;38;55-59]. The criteria for decision making on their use in healthcare will also include cost consequences.

Key summary point

There is a lack of evidence regarding the effectiveness of these rapid tests in reducing transmission of MRSA

11.1.15 Aim 2 Objective 15: To examine the potential for new technologies or approaches to offer better value for money

Value for money judgements in healthcare require defined outcomes, in this case MRSA disease reduction, and opportunity cost saving from a reduction in these outcomes. Financial evaluation of the impact of screening has been addressed in a recent large cohort study by Hacek and colleagues [60]. This study of universal screening in three hospitals found a reduction in MRSA disease and overall S. aureus isolates as a result of the screening intervention and concluded that assessing the financial impact of a MRSA control programme should include a control group with no S. aureus as a comparator, as opposed to MSSA as a comparator. Their study suggested there was no financial benefit in avoiding MRSA infection compared with MSSA, an outcome not seen when prevention of MRSA disease was the control group with no S.aureus infection.

Costs of technologies such as laboratory tests require evaluation in terms of the sensitivity and specificity of the test as well as the costs. The costs of PCR tests are currently higher than that of culture methods [33;34;37;47;48]. One recent paper suggested that PCR was ten times more expensive in their setting [34]. The pathfinder project study allowed NHS QIS to recalculate the costs of technologies for the HTA model (see section 10.1 page 79) and these recalculations indicated that PCR was proportionately more expensive than the assumptions in the original HTA model. The findings from the pathfinder project indicate that real time PCR is three times more expensive than chromogenic agar for MRSA negative tests, and four times more expensive for positive MRSA tests since follow-up tests are still required.

Whilst current evidence, from this study and others, points to chromogenic agars being the most cost effective strategy for universal MRSA screening [2], there are clearly limitations to using this test at hospital admission due to the turn around time and short lengths of stay for most patients. It does however work in those patients who are seen at preadmission clinics in terms of confirming their MRSA status preadmission. It is therefore essential that there is ongoing monitoring of the emerging molecular techniques of PCR and the associated evidence base. If and when evidence from studies demonstrate that these methods provide benefits in patient care and/or containment of MRSA that outweigh the higher costs of testing, consideration should be given to introducing them. In the meantime the use of rapid tests requires further study [31].

On the basis that there is no perfect laboratory test fit for purpose, in terms of turnaround time and sensitivity and specificity, which is also inexpensive, the case for clinical risk assessment as a screening tool has been made by some authors [53;61-65]. Knowledge of the variables that identify patients with higher risk of being carriers or infected with MRSA, may assist clinicians in targeting preventative measures at the point of admission. The predictive power of the tools used varies by the setting it is applied within, and the risk factors included. The NHS QIS HTA model assumption around clinical risk assessment was based on a tool used by an NHS board. This tool was a comprehensive list of risk factors and as such took time to complete for each patient. The time taken to complete this risk assessment was what made it more expensive in the economic model. To date, there is a

plethora of papers on the risk factors which predict MRSA colonisation [53;61-65], but no consensus on which ones matter most and no gold standard risk assessment tool. Harbarth and colleagues [63] have indicated recently that limiting clinical risk assessment on admission to three factors: recent antibiotic treatment, history of hospitalisation and age older than 75 years) in a surgical unit correctly identified 53% of carriers. However the critical risk factors for predicting risk of MRSA colonisation in all acute hospital patients remain unknown and require further research. This topic is the subject of a special research study within the MRSA screening programme, due for publication in 2010.

The debate in the literature continues on the role of targeted versus universal screening [65], interestingly many of the review papers fail to acknowledge the contribution of the NHS QIS HTA to the evidence base on economic modelling [65] and continue to call for economic modelling to compare targeted with universal screening. The HTA remains the best available evidence to date in this area.

Other approaches which could offer better value for money have been discussed in the literature since the publication of the HTA. A review of the literature on screening and isolation by Tacconelli [53] this year concludes that programmes focussing solely on MRSA might not be the answer. The authors propose that using alcohol hand rubs and behavioural change interventions might be a more cost effective approach to reduce infections when compared to universal screening for one organism of concern.

Key summary point

The debate in the literature continues on the role of targeted versus universal screening

11.1.16 Aim 2 Objective 16: To quantify the staff time taken to carry out screening for MRSA colonisation (versus previous risk assessment time)

The pathfinder project was developed in line with the HTA strategy 2, which was to screen all admissions and hold them in a receiving ward until their results where known within 24 hours. At the outset of the pathfinder project, it was recognised that existing practice was that patients were admitted to specialties across the hospital without a confirmed result and therefore existing clinical risk assessment practice continued in the NHS boards. Those patients who were risk assessed as probable colonisations on admission were pre-emptively cohorted or isolated pending the laboratory confirmation.

In recognition of the limitations of the evidence in the published literature to support the NHS QIS HTA with respect to clinical risk assessment, part of the scope of the pathfinder project was to quantify the time taken for this clinical risk assessment. The results from this were presented in Table 9-25 and indicated that the median time to undertake clinical risk assessment was six minutes per patient compared with five and a half minutes for nasal

screening. The differential in time between the two approaches is not as great as the HTA assumed it would be and therefore calls into question the assumptions on timing of clinical risk assessment and subsequent comparative costs for the economic modelling.

The pathfinder project also measured time taken for full body site screening and the results indicated that this was nine and a half minutes, which is significantly longer than nasal or clinical risk assessment time alone. This suggests that universal screening utilising more than nasal screening would have significant cost consequences for NHSScotland.

Key summary point

The differential in time between universal screening and clinical risk assessment is not as great as the HTA assumed. This reflects the value in investigating clinical risk assessment and the subsequent comparative costs.

11.1.17 Aim 2 Objective 17: To carry out an economic analysis of the costs effectiveness of the programme in the context of other possible interventions to reduce MRSA in NHSScotland

On balance it appears that the additional cost of universal screening will be £15 million pounds per year, the total number infections potentially avoided (if we were able to maintain the annual decrease observed within the Pathfinder hospitals) it is estimated that over five years universal screening of all overnight admissions would prevent 15,000 infections. There are costs associated with each of these infections in terms of additional length of stay, additional treatment costs and resources associated with follow-up in primary care. Costs to patients and their carers would also be incurred. Targeted screening would prevent a proportion of these 15,000 infections; however, the magnitude of this proportion is as yet unquantifiable.

The possible negative impact of both universal and targeted screening is the potential increase in mupirocin resistance. The second possible negative impact could be the replacement of MRSA with another organism. Both of these issues should continue to be monitored.

11.2 Task 2: To re-populate the model produced during the NHS QIS HTA using the parameters collected within the Pathfinder project

Significant differences were shown in the parameters estimated (Table 10-1) and the assumptions used (Table 10-8) within the NHS QIS HTA and those measured within the Pathfinder project.

There was an expectation that the NHS QIS HTA model would allow parameters measured in the Pathfinder study to be used to update the model and then undertake a comparison of predicted decline in MRSA colonisation and infection compared with observed MRSA colonisation and infection. Had the assumptions within the model design been shown to be true, this may have been possible, however many of these assumptions were found not to be observed in reality.

When the model was initially re-run the result was a half empty hospital as patient movement was limited as the model did not allow patients to be moved to a specialist ward until they received test results. The model was altered to allow patients to be moved before their test results were available and the results are summarised. A number of further iterations of the model were attempted all of which gave outputs which were not representative of the findings of the Pathfinder. It was decided at this time since small changes were being made to the model that there could not be a like with like comparison with the NHS QIS HTA and that the model should be re-designed to take into account the changes to the assumptions recorded in the Pathfinder Project.

Key summary point

The differences observed within the Pathfinder study from the assumptions used in the NHS QIS HTA were considered so great that the model was re-designed to account for these variations.

11.3 Task 3: Review the overall effect on the outcomes and compare the model output to the effect found within the Pathfinder Boards

As many of the assumptions were built into this model and results are presented for the re-worked model. This task was undertaken, however the results found and presented in section 10 meant that re-population of the model was not pursued.

11.4 Task 4: To alter the model taking into account the assumptions made in the design of the model and to use the knowledge gathered during the Pathfinder Project in order to ensure the model design is robust and based on health service reality

The developments required in order to make the original model reflect the findings of the Pathfinder project required so many changes that a like with like comparison with NHS QIS HTA predictions was not possible. The model was dependent on assumptions and proportions of admissions in categories that were found to be significantly different in the pathfinder project. The changes made to the model were extensive (see Table 7-3).

Work is currently underway for peer review of the model and the changes made to it. This is being undertaken by University of Abertay (See 15 Appendix 1: MRSA Screening Economic Model and Section 12 Recommendations)

11.5 To consider the implications and cost predictions of the model compared to the findings of the Pathfinder project and consider the implications for MRSA screening in NHSScotland

The NHS QIS HTA recommended strategy 2 (universal screening), which required the lowest investment and provided the best consequences as a result of that investment (i.e. highest reduction in MRSA colonisation and thereby infection for a set amount of funding).

When the model was re-designed and the parameters measured within the Pathfinder project used, the outcome appeared to support the decision to recommend direct chromogenic agar testing and universal screening. The intervention of screening made a significantly better impact on MRSA colonisation and infection over the five year time period it displays. The option of no screening which includes the isolation of infected patients only with no screening still incurs a significant cost (this is attributable to cost of isolation). This cost will not be additional to the current hospital budget since staffing and facilities of isolation rooms is covered by existing budgets. The relative cost of these strategies is balanced against the reduction in colonisation and infections prevented. For a large general hospital if we assume that the strategy 1 baseline option is what is happening currently in NHS Scotland then, strategy 1, (no screening) represents the number of infections expected in a control hospital. The investment for strategy 2 chromogenic agar in a tertiary referral hospital, 1,341 infections will be prevented (885 infections will still occur). Colonisation will be reduced from 5.5% to 0.4% within five years compared to 1.8% for do nothing. (Table 10-15,

Table 10-17). With strategy 2 PCR the cost is twice that of Chromogenic agar for both tests will give a total of 999 infections prevented (1,227 infections will still occur) and colonisation will also be reduced from 5.5% to 0.8% within five years. It is interesting to note that the implementation of universal screening using chromogenic agar is actually cheaper within five years than no screening, due to the reduction in number of infections.

These analyses were designed to be comparative and not predictive. MRSA screening appears to provide a significant reduction in MRSA infection and colonisation over five years, based on the parameters measured within the Pathfinder programme. This is supported by the findings of the trends in MRSA infections in Pathfinder hospitals compared to non pathfinder hospitals within the same health boards. The confidence in the prediction of the cost for investment and the consequence of that investment is not great enough to allow a recommendation for universal screening to be recommended by this model. Instead the weight of decision making must be placed on the data collected within the Pathfinder project assessed against the public health principles of implementing a screening programme. These data describe a large number of (N=81,438) patient admission episodes and their outcomes. The resource cost of the implementation of the current screening strategy is described in Volume 4 Organisational Issues. Although costs were derived from the original NHS QIS HTA resource allocation has been made using a spreadsheet based on the findings of the Pathfinder study, this is considered to be a better predictor of anticipated cost than the NHS QIS HTA model.

The effect of chromogenic agar compared with PCR does not vary greatly except for cost. As the cost of rapid technologies reduces the use of new technologies should be reviewed for use in NHSScotland by a suitable review panel. It is recommended that conclusions must be drawn from the Clinical effectiveness and the Implementation issues which are measures of the findings of implementing universal screening in a real environment.

Key summary point

MRSA screening appears to provide a significant reduction in infection and colonisation over five years, based on the parameters measured within the Pathfinder programme. Chromogenic agar and PCR appear to have a comparable effect based on the model output however PCR remains considerably more costly.

12 Recommendations

The Pathfinder data evaluated against the public health principles of implementing an MRSA screening programme should be the primary source used in the decision making of whether a long term investment in universal MRSA screening is made.

It is recommended that conclusions must be drawn from the Clinical effectiveness and the Implementation issues which are measures of the findings of implementing universal screening in a real environment.

Consideration should be given to developing an agent based model based on the knowledge gained within the Pathfinder study which could be used as a tool in development of national and local MRSA screening policies.

There are many gaps in the research underpinning the evidence required to fully assess the implementation of universal screening. Further investigation into transmission within hospital and the use of clinical risk assessment are recommended.

13 Limitations of the study/modelling

This study was an implementation study to see if the findings of the NHSQIS HTA were borne out and to assess if the strategy described could be implemented. The resulting outputs from the model are projections not predictions.

The modelling work develops the original stochastic model developed for the NHS QIS HTA, this presented a number of issues given the findings of the Pathfinder project, an agent based model is recommended for future modelling.

The results are for three health boards within Scotland, each having specific patient populations; they represent a large tertiary referral hospital, two large general hospitals and two small general hospitals. This was not an attempt to exactly model healthcare in NHSScotland however the results of the implementation are thought to be generally transferrable to NHS Scotland.

Some parameters used in the model are the original assumptions (readmission rates, hospital size) and were not calculated by the Pathfinder study as they would require larger studies outwith the remit of the project.

The model is a simplification of healthcare and only considers the single issue of MRSA with screening and the interventions of isolation and decolonisation.

Within the model the likelihood of infection or colonisation equal throughout stay, no studies have been found to provide any improved parameters around this.

Model assumes Isolation reduced transmission to zero

The model does not account for staff or patient cohorting

14 Reference List

[1] Cooper BS, Stone SP, Kibbler CC, Cookson BD, Roberts JA, Medley GF, *et al*. Systematic review of isolation policies in the hospital management of methicillin-resistant *Staphylococcus aureus*: a review of the literature with epidemiological and economic modelling. Health Technol Assess 2003;7(39):1-194.

[2] Ritchie K, Craig J, Eastgate J, Foster L, Kohli H, Iqbal K, *et al*. The clinical and cost effectiveness of screening for meticillin-resistant *Staphylococcus aureus* (MRSA). Edinburgh: NHS Quality Improvement Scotland; 2007.

[3] Health Protection Scotland on behalf of Pathfinder Health Boards. Final report volume 1: An investigation of the clinical effectiveness of MRSA screening. Glasgow: Health Protection Scotland; 2009 Dec. Report No.: Vol. 1

[4] Health Protection Scotland. NHS Scotland MRSA screening pathfinder programme - Interim report. Glasgow: Health Protection Scotland; 2009.

[5] Coia JE, Duckworth GJ, Edwards DI, Farrington M, Fry C, Humphreys H, *et al*. Guidelines for the control and prevention of meticillin-resistant *Staphylococcus aureus* (MRSA) in healthcare facilities. J Hosp Infect 2006 May;63 Suppl 1:S1-44.

[6] Bissett L. Controlling the risk of MRSA infection: screening and isolating patients. Br J Nurs 2005 Apr 14;14(7):386-90.

[7] Cooper B, Lipsitch M. The analysis of hospital infection data using hidden Markov models. Biostatistics 2004 Apr;5(2):223-37.

[8] Farr BM. Prevention and control of methicillin-resistant *Staphylococcus aureus* infections. Curr Opin Infect Dis 2004 Aug;17(4):317-22.

[9] Herr CE, Heckrodt TH, Hofmann FA, Schnettler R, Eikmann TF. Additional costs for preventing the spread of methicillin-resistant *Staphylococcus aureus* and a strategy for reducing these costs on a surgical ward. Infect Control Hosp Epidemiol 2003 Sep;24(9):673-8.

[10] Rubinovitch B, Pittet D. Screening for methicillin-resistant *Staphylococcus aureus* in the endemic hospital: what have we learned? J Hosp Infect 2001 Jan;47(1):9-18.

[11] Wernitz MH, Keck S, Swidsinski S, Schulz S, Veit SK. Cost analysis of a hospital-wide selective screening programme for methicillin-resistant *Staphylococcus aureus* (MRSA) carriers in the context of diagnosis related groups (DRG) payment. Clin Microbiol Infect 2005 Jun;11(6):466-71.

[12] Chaix C, Durand-Zaleski I, Alberti C, Brun-Buisson C. Control of endemic methicillin-resistant *Staphylococcus aureus*: a cost-benefit analysis in an intensive care unit. JAMA 1999 Nov 10;282(18):1745-51.

[13] Health Technology Board for Scotland. Guidance for manufacturers on submission of evidence to health technology assessments. Glasgow: Health Technology Board for Scotland; 2002.

[14] Health Protection Scotland on behalf of Pathfinder Health Boards. Final report volume 4: To evaluate the feasibility and potential for rollout of the MRSA screening programme. Glasgow: Health Protection Scotland; 2009 Dec. Report No.: Vol. 4

[15] In-patient, day case and outpatient activity. Information Services Division 2009 May 26 [cited 2009 Sep 18];Available from: URL: http://www.isdscotland.org/isd/4150.html

[16] Siegel JD, Rhinehart E, Jackson M, Chiarello L, the Healthcare Infection Control Practices Advisory Committee. Management of multidrug-resistant organisms in health care settings. Atlanta: Centers for Disease Control and Prevention; 2006.

[17] Rohr U, Mueller C, Wilhelm M, Muhr G, Gatermann S. Methicillin-resistant *Staphylococcus aureus* whole-body decolonization among hospitalized patients with variable site colonization by using mupirocin in combination with octenidine dihydrochloride. J Hosp Infect 2003 Aug;54(4):305-9.

[18] National Nursing Research Unit. Does "cohort nursing" help control healthcare acquired infection? Kings College London 2007 [cited 9 A.D. Oct 5];Available from: URL: http://www.kcl.ac.uk/content/1/c6/03/09/92/PolicyIssue4.pdf

[19] Williamson T. HR Advisor, NHS Quality Improvement Scotland. 2009.
Ref Type: Personal Communication

[20] Stewart G. Materials Planning Manager, NHS National Procurement. 2009.
Ref Type: Personal Communication

[21] Hornby P. Strategic Sourcing Manager, NHS National Procurement. 2009.
Ref Type: Personal Communication

[22] MacKenzie FM. Microbiologist, Aberdeen Royal Infirmary. 2009.
Ref Type: Personal Communication

[23] Walker A. Managing Director, Cepheid Europe. 2009.
Ref Type: Personal Communication

[24] British National Formulary. British Medical Association; Royal Pharmaceutical Society of Great Britain; 2008.

[25] Oduro S. Inpatient records for year ended 31 March 2005 (Communication to QIS). Quality Improvement Scotland, editor. 2007.
Ref Type: Personal Communication

[26] Ben NS, Dupuis M, Leclercq R. Evaluation of MRSA Select, a new chromogenic medium for the detection of nasal carriage of methicillin-resistant *Staphylococcus aureus*. Int J Antimicrob Agents 2006 Jun;27(6):561-4.

[27] Stoakes L, Reyes R, Daniel J, Lennox G, John MA, Lannigan R, *et al*. Prospective comparison of a new chromogenic medium, MRSASelect, to CHROMagar MRSA and mannitol-salt medium supplemented with oxacillin or cefoxitin for detection of methicillin-resistant *Staphylococcus aureus*. J Clin Microbiol 2006 Feb;44(2):637-9.

[28] Gopal RG, Michalczyk P, Nayeem N, Walker G, Wigmore L. Prevalence and risk factors for meticillin-resistant *Staphylococcus aureus* in adult emergency admissions--a case for screening all patients?[see comment]. Journal of Hospital Infection 2007 May;66(1):15-21.

[29] Transmission based precautions. Health Protection Scotland 2009 [cited 2009 Nov 11];Available from: URL: http://www.hps.scot.nhs.uk/haiic/ic/transmissionbasedprecautions.aspx?subjectid=00D2

[30] Single room provision steering group report. Scottish Government 2008 [cited 2009 Nov 11];Available from: URL: http://www.scotland.gov.uk/Resource/Doc/253500/0075129.pdf

[31] Tacconelli E, De AG, de WC, Cataldo MA, La TG, Cauda R. Rapid screening tests for meticillin-resistant *Staphylococcus aureus* at hospital admission: systematic review and meta-analysis. Lancet Infect Dis 2009 Sep;9(9):546-54.

[32] Carroll KC. Rapid diagnostics for methicillin-resistant *Staphylococcus aureus*: current status. Mol Diagn Ther 2008;12(1):15-24.

[33] Malhotra-Kumar S, Haccuria K, Michiels M, Ieven M, Poyart C, Hryniewicz W, *et al*. Current trends in rapid diagnostics for methicillin-resistant *Staphylococcus aureus* and glycopeptide-resistant enterococcus species. J Clin Microbiol 2008 May;46(5):1577-87.

[34] Dalla VC, Pasca MR, De VD, Capra MF, Emmi V, Marone P. Control of MRSA infection and colonisation in an intensive care unit by GeneOhm MRSA assay and culture methods. BMC Infect Dis 2009 Aug 24;9(1):137.

[35] van Hal SJ, Jennings Z, Stark D, Marriott D, Harkness J. MRSA detection: comparison of two molecular methods (BD GeneOhm PCR assay and Easy-Plex) with two selective MRSA agars (MRSA-ID and Oxoid MRSA) for nasal swabs. Eur J Clin Microbiol Infect Dis 2009 Jan;28(1):47-53.

[36] Bishop EJ, Grabsch EA, Ballard SA, Mayall B, Xie S, Martin R, *et al*. Concurrent analysis of nose and groin swab specimens by the IDI-MRSA PCR assay is comparable to analysis by individual-specimen PCR and routine culture assays for detection of colonization by methicillin-resistant *Staphylococcus aureus*. J Clin Microbiol 2006 Aug;44(8):2904-8.

[37] Boyce JM, Havill NL. Comparison of BD GeneOhm methicillin-resistant *Staphylococcus aureus* (MRSA) PCR versus the CHROMagar MRSA assay for screening patients for the presence of MRSA strains. J Clin Microbiol 2008 Jan;46(1):350-1.

[38] Daeschlein G, Assadian O, Daxboeck F, Kramer A. Multiplex PCR-ELISA for direct detection of MRSA in nasal swabs advantageous for rapid identification of non-MRSA carriers. Eur J Clin Microbiol Infect Dis 2006 May;25(5):328-30.

[39] de SN, Denis O, Gasasira MF, De MR, Nonhoff C, Struelens MJ. Controlled evaluation of the IDI-MRSA assay for detection of colonization by methicillin-resistant *Staphylococcus aureus* in diverse mucocutaneous specimens. J Clin Microbiol 2007 Apr;45(4):1098-101.

[40] Desjardins M, Guibord C, Lalonde B, Toye B, Ramotar K. Evaluation of the IDI-MRSA assay for detection of methicillin-resistant *staphylococcus aureus* from nasal and rectal specimens pooled in a selective broth. J Clin Microbiol 2006 Apr;44(4):1219-23.

[41] Francois P, Bento M, Renzi G, Harbarth S, Pittet D, Schrenzel J. Evaluation of three molecular assays for rapid identification of methicillin-resistant *Staphylococcus aureus*. J Clin Microbiol 2007 Jun;45(6):2011-3.

[42] Holfelder M, Eigner U, Turnwald AM, Witte W, Weizenegger M, Fahr A. Direct detection of methicillin-resistant *Staphylococcus aureus* in clinical specimens by a nucleic acid-based hybridisation assay. Clin Microbiol Infect 2006 Dec;12(12):1163-7.

[43] Jeyaratnam D, Gottlieb A, Ajoku U, French GL. Validation of the IDI-MRSA system for use on pooled nose, axilla, and groin swabs and single swabs from other screening sites. Diagn Microbiol Infect Dis 2008 May;61(1):1-5.

[44] Johnson G, Millar MR, Matthews S, Skyrme M, Marsh P, Barringer E, *et al*. Evaluation of BacLite Rapid MRSA, a rapid culture based screening test for the detection of ciprofloxacin and methicillin resistant S. aureus (MRSA) from screening swabs. BMC Microbiol 2006;6:83.

[45] Kobayashi N, Inaba Y, Choe H, Iwamoto N, Ishida T, Yukizawa Y, *et al*. Rapid and sensitive detection of methicillin-resistant Staphylococcus periprosthetic infections using real-time polymerase chain reaction. Diagn Microbiol & Infect Dis 2009 Jun;64(2):172-6.

[46] Levi K, Towner KJ. Rapid detection of methicillin-resistant *Staphylococcus aureus* from screening enrichment broths by real-time PCR. Eur J Clin Microbiol Infect Dis 2005 Jun;24(6):423-7.

[47] Paule SM, Hacek DM, Kufner B, Truchon K, Thomson RB, Jr., Kaul KL, *et al*. Performance of the BD GeneOhm methicillin-resistant *Staphylococcus aureus* test before and during high-volume clinical use. J Clin Microbiol 2007 Sep;45(9):2993-8.

[48] Rajan L, Smyth E, Humphreys H. Screening for MRSA in ICU patients. How does PCR compare with culture? J Infect 2007 Oct;55(4):353-7.

[49] Rossney AS, Herra CM, Brennan GI, Morgan PM, O'Connell B. Evaluation of the Xpert methicillin-resistant *Staphylococcus aureus* (MRSA) assay using the GeneXpert real-time PCR platform for rapid detection of MRSA from screening specimens. J Clin Microbiol 2008 Oct;46(10):3285-90.

[50] van Hal SJ, Stark D, Lockwood B, Marriott D, Harkness J. Methicillin-resistant *Staphylococcus aureus* (MRSA) detection: comparison of two molecular methods (IDI-MRSA PCR assay and GenoType MRSA Direct PCR assay) with three selective MRSA agars (MRSA ID, MRSASelect, and CHROMagar MRSA) for use with infection-control swabs. J Clin Microbiol 2007 Aug;45(8):2486-90.

[51] Bartels MD, Boye K, Rohde SM, Larsen AR, Torfs H, Bouchy P, *et al*. A common variant of staphylococcal cassette chromosome mec type IVa in isolates from Copenhagen, Denmark, is not detected by the BD GeneOhm methicillin-resistant *Staphylococcus aureus* assay. J Clin Microbiol 2009 May;47(5):1524-7.

[52] Wolk DM, Picton E, Johnson D, Davis T, Pancholi P, Ginocchio CC, *et al*. Multicenter evaluation of the Cepheid Xpert methicillin-resistant *Staphylococcus aureus* (MRSA) test as a rapid screening method for detection of MRSA in nares. J Clin Microbiol 2009 Mar;47(3):758-64.

[53] Tacconelli E. Screening and isolation for infection control. J Hosp Infect 2009 Aug 20;73(4):371-7.

[54] Wigglesworth N, Wilcox MH. Prospective evaluation of hospital isolation room capacity. J Hosp Infect 2006 Jun;63(2):156-61.

[55] Struelens MJ, Denis O. Rapid molecular detection of methicillin-resistant *Staphylococcus aureus*: a cost-effective tool for infection control in critical care? Crit Care 2006;10(2):128.

[56] Aldeyab MA, Kearney MP, Hughes CM, Scott MG, Tunney MM, Gilpin DF, *et al*. Can the use of a rapid polymerase chain screening method decrease the incidence of nosocomial meticillin-resistant *Staphylococcus aureus*? J Hosp Infect 2009 Jan;71(1):22-8.

[57] Bootsma MC, Diekmann O, Bonten MJ. Controlling methicillin-resistant *Staphylococcus aureus*: quantifying the effects of interventions and rapid diagnostic testing. Proc Natl Acad Sci U S A 2006 Apr 4;103(14):5620-5.

[58] Uckay I, Sax H, Iten A, Camus V, Renzi G, Schrenzel J, *et al*. Effect of screening for methicillin-resistant *Staphylococcus aureus* carriage by polymerase chain reaction on the duration of unnecessary preemptive contact isolation. Infect Control Hosp Epidemiol 2008 Nov;29(11):1077-9.

[59] Health Protection Scotland on behalf of Pathfinder Health Boards. Final report volume 3: Staff patient acceptability. Glasgow: Health Protection Scotland; 2009 Dec. Report No.: Vol. 3

[60] Hacek DM, Paule SM, Thomson RB, Jr., Robicsek A, Peterson LR. Implementation of a universal admission surveillance and decolonization program for methicillin-resistant *staphylococcus aureus* (MRSA) reduces the number of MRSA and total number of S. aureus isolates reported by the clinical laboratory. J Clin Microbiol 2009 Nov;47(11):3749-52.

[61] Eveillard M, Lancien E, Barnaud G, Hidri N, Gaba S, Benlolo JA, *et al*. Impact of screening for MRSA carriers at hospital admission on risk-adjusted indicators according to the imported MRSA colonization pressure. J Hosp Infect 2005 Mar;59(3):254-8.

[62] Harbarth S, Sax H, Fankhauser-Rodriguez C, Schrenzel J, Agostinho A, Pittet D. Evaluating the probability of previously unknown carriage of MRSA at hospital admission. Am J Med 2006 Mar;119(3):275-23.

[63] Harbarth S, Sax H, Uckay I, Fankhauser C, Agostinho A, Christenson JT, *et al*. A predictive model for identifying surgical patients at risk of methicillin-resistant *Staphylococcus aureus* carriage on admission. J Am Coll Surg 2008 Nov;207(5):683-9.

[64] Lucet JC, Chevret S, Durand-Zaleski I, Chastang C, Regnier B. Prevalence and risk factors for carriage of methicillin-resistant *Staphylococcus aureus* at admission to the intensive care unit: results of a multicenter study. Arch Intern Med 2003 Jan 27;163(2):181-8.

[65] Tacconelli E. Methicillin-resistant *Staphylococcus aureus*: risk assessment and infection control policies. Clin Microbiol Infect 2008 May;14(5):407-10.

[66] Jonsson E, Banta HD, Henshall C, Sampietro-Colom L. Summary report of the ECHTA/ECAHI project. European Collaboration for Health Technology Assessment/Assessment of Health Interventions. Int J Technol Assess Health Care 2002;18(2):218-37.

[67] Taguchi G. Introduction to Quality Engineering. Tokyo: Asian Productivity Organisation; 1986.

[68] Saltelli A, Ratto M, Andres T, Campolongo F, Cariboni J, Gatelli D, *et al*. Global sensitivity analysis. The primer. USA: John Wiley & Sons; 2008.

[69] Railsback SF. Concepts from complex adaptive systems as a framework for individual-based modelling. Ecol Modell 2001 Mar 30;139(1):47-62.

[70] Tumer K, Agogina A. Distributed agent-based air traffic flow management. 6th Int. Joint Conf. on Autonomous Agents and Multi-Agent Systems (AAMAS '07). Hawaii 2007.

[71] Segovia-Juarez JL, Ganguli S, Kirschner D. Identifying control mechanisms of granuloma formation during M. tuberculosis infection using an agent-based model. J Theor Biol 2004 Dec 7;231(3):357-76.

[72] Bonabeau E. Agent-based modeling: methods and techniques for simulating human systems. Proc Natl Acad Sci U S A 2002 May 14;99 Suppl 3:7280-7.

15 Appendix 1: MRSA Screening Economic Model

15.1 Summary of review of economic model approach

This document reviews the development and implementation of a model that compares different strategies for screening MRSA with respect to cost. The substantive part of this model development was completed in 2007, and this work has already been reviewed. We consider a number of extensions to that original work that have been motivated by new knowledge. We review both the overall methodology, and the specific implementation of the desired changes together with the capacity of the revised model architecture to accommodate relevant data. We conclude with a series of recommendations on how best to further support strategic planning of screening strategies in particular and intervention measures generally.

15.2 Key findings and recommendations

We find that:

- the model as developed has partly fulfilled it original intent of isolating and identifying the economics of the different testing strategies for MRSA;
- the model is a descriptive tool able to compare, understated assumptions, the costs of different strategies;
- the model has served as an effective tool in increasing the understanding of the nature of the problem, the system level and operational constraints involved, baseline results and the nature and sources of the core data.

Working from this base it is possible to define the requirements and specifications for a next generation model which will, when combined with current system understanding and data sources, provide a predictive framework to support decision making in relation to screening strategies and other related policies. We recommend a modelling strategy that is able to:

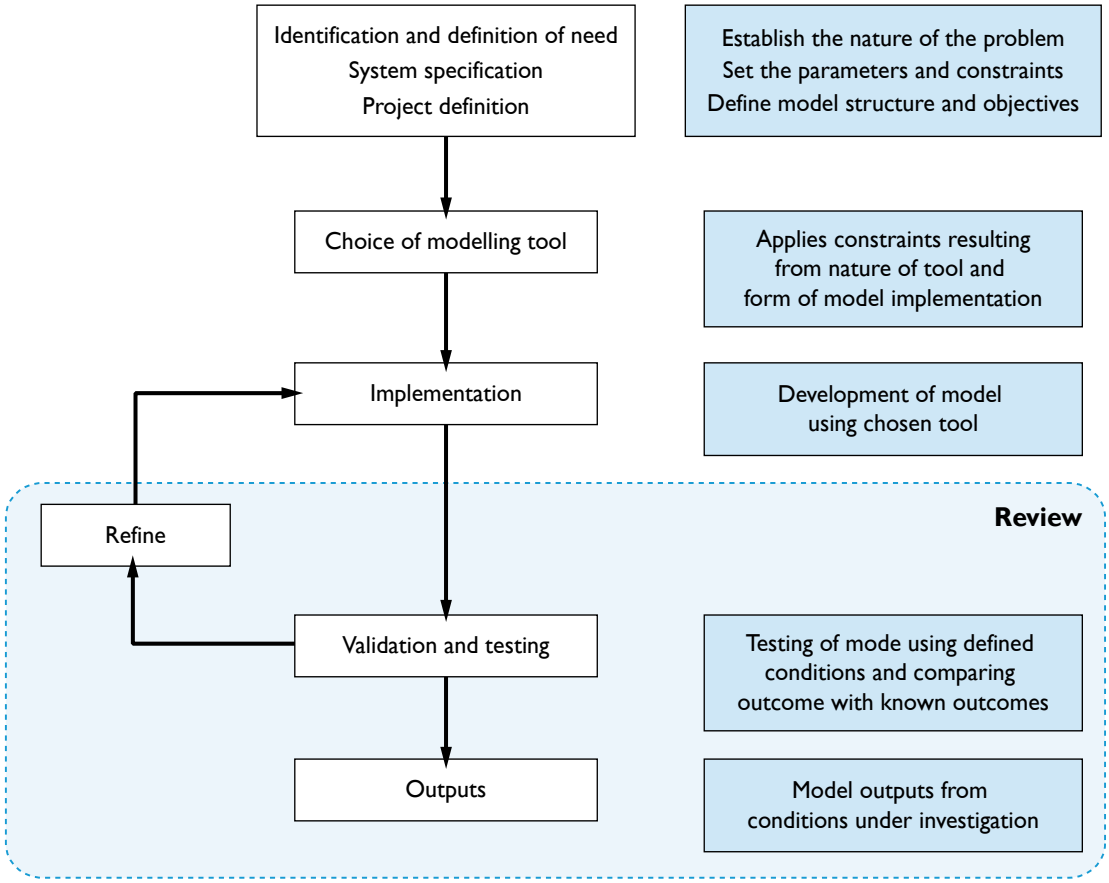
- predict the impact of screening and other costed management strategies on prevalence of HAI, incorporating existing knowledge, including uncertainties in that knowledge, and accommodate new data as and when it becomes available;
- represent individual patients and carers, to provide variation among individuals in terms of their characteristics and to link these to observed patient and carer data, and explore the impact on prevalence of different patient and carer cohorting strategies together with different ward configurations and bed occupancy profiles.

We propose that, given the modelling work undertaken to date combined with the knowledge and data derived from the pathfinder study, this is an opportunity to undertake detailed agent-based modelling of the system. This would provide a platform for developing a more complex, powerful tool for predictive modelling to inform decisions on costed management of infection control.

15.3 Methodology

While the brief for this review is to look at the outcomes from the modeling process it is necessary to consider the background to the work in order to place the comments into a proper context. Figure 15-1 therefore provides a simplified overview of the processes and procedures leading to the model outcomes with the area of attention for the review outlined.

Figure 15-1: Simplified development process



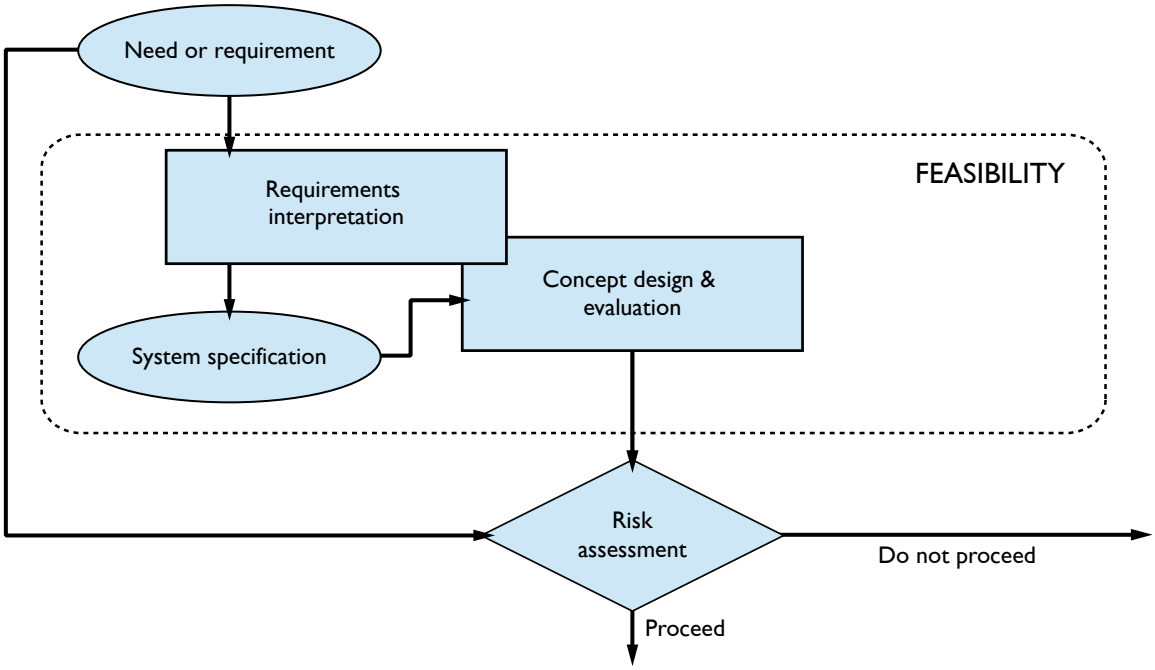
When designing a complex piece of software it is key to ensure that all parties are aware of the aim of the software, its structure and the necessary constraints placed upon the model[1]. In this case it is stated that the approach was based on established NHS QIS HTA methodology which itself was based on the ECHTA model [66] of four elements - clinical effectiveness; economic evaluation; patient issues and organisational issues. For each of these elements a series of activities are proscribed within internal manuals and associated timelines[2].

This format aims to ensure that the process follows a formal progression over the duration of the project. However, without looking at the implementation in this case, it is not possible to identify if certain elements that it might be expected to find are actually embedded in the process. These include:

- the procedures for defining project milestones and the gatekeeper action associated with each milestone;
- the existence of any oversight role separate from the core project team to link into the gatekeeper in relation to the decision making processes;
- the means for identifying the evaluation criteria associated with each milestone.

Figure 15-2 provides a simple illustration of the overall decision making process in the system specification and project definition phases of the project.

Figure 15-2: Simplified representation of a decision making process leading to a go/no-go outcome



1 See Royal Academy of Engineering/BCS report *The Challenges of Complex IT Projects* and the follow up report *Engineering Values in IT* on this.

2 See the document *Development of economic model for HTA on screening for MRSA* - The clinical and cost effectiveness of screening for meticillin-resistant *Staphylococcus aureus*. Ritchie *et al*. NHS Quality Improvement Scotland 2007

In the case of a model such as that being proposed, it might be expected that factors such as the modelling method to be used, in this case the modelling software, would be evaluated against the model objectives and any limitations imposed by the modelling process identified and isolated. With regard to the testing of the model, it would be expected that the criteria for evaluation are established separately from the model once the key parameters have been identified. This would include both the functional and boundary parameters within which the model was to operate and the expected ranges for those parameters together with the test cases to be used. Once this has been done, the model can be developed 'blind' to avoid foreknowledge of the outcomes influencing the model structure.

In this case, an illustration of a boundary parameter would be the bed occupancy rates assumed and the variation in this that occurs between, for example, winter and summer months. This means that running the model with a single, fixed, value for bed occupancy may reflect only one set of conditions (i.e. winter or summer) depending on the value chosen. An example of an operating parameter may be the time taken for the results of any tests to be returned as the time between taking the swabs and the results being returned can influence the way in which the model interprets the outcomes. In general, such processes would be represented not by a simple, single time but as a probabilistic distribution around a mean time, which itself may be influenced by factors such as capacity; i.e. if the load increased as represented by the demand for tests, the time taken to return the results will increase.

In terms of validating the model, it would normally be expected that there would be a number of known scenarios against which the model would be tested and the outputs compared. If these outputs are within the defined tolerance bands for the performance of the model, operation can then be extended to unknown cases and scenarios.

Finally, given the nature of the problem, it would be expected that some form of analysis involving both the functional and boundary parameters would be deployed to generate a range of outcomes and to isolate those parameters to which the outcomes are most sensitive. This would mean that the results would be presented with associated tolerances or error bounds. Such analysis would be considered as forming part of a standard experimental procedure.

15.3.1 Operating Constraints

In any modelling exercise, the structure of the model, and of the modelling software, can influence the outcomes. In general therefore there is a need to place the outcomes into the context of the model and the way it was constructed, including the software used. In this case, the emphasis was purely on establishing the economic impact on the monitoring and control of MRSA through the deployment of specific swabbing and testing strategies. These strategies were:

- no carriage assessment, no swab screening;
- no carriage assessment, swab screening of all patients;
- no carriage assessment, swab screening of all High Risk unit patients only;
- carriage assessment of all patients and swab tests for 'likely' carriers;
- carriage assessment of all low risk patients, swab screening of all high risk patients and likely low risk carriers;
- carriage assessment of all patients, preemptive isolation based on carriage assessment, and swab screening of all high risk patients.

In addition, patients were to be grouped according to their age group and risk category. The relationships for the risk categories are then as set out in Table 15-1. This means that all other parameters are to be considered as bounding parameters.

Table 15-1: Deployment of strategies

Strategy	Carriage assessment - High risk units	Carriage assessment - Low risk units	Swab screening - High risk units	Swab screening† - Low risk units
1	No	No	No	No
2	No	No	Yes	Yes
3	No	No	Yes	No
4	Yes	Yes‡	No	No
5	No	Yes‡	Yes	No
6	Yes	Yes‡	Yes	Yes

15.3.2 Testing and Validation

To ensure a robust testing and validation regime it is necessary to define the test parameters at the time of establishing the model parameters along with the way in which the tests are to be carried out. This generally requires establishing early on and independently of the modelling process a set of test data and validated outcomes associated with test data.

The uncertainty in the outcomes also needs to be established, and it would generally be anticipated that the output would define the boundaries rather than provide an absolute value. In particular, where there are significant uncertainties in the data, the outcomes cannot, and should not, be quoted as a single figure with no indication of the associated uncertainty. We recognise that within the context of a large data collection and analysis exercise, which would form the basis of model and test parameters, NHS Scotland have undertaken this. From this analysis there exist mean values, or other measures of distribution, and associated confidence intervals for these values to the model parameters. These are presented elsewhere in the documentation describing the project as a whole and we refer the reader to this.

15.3.3 Sensitivity Analysis

In any modelling process, the model will demonstrate different levels of sensitivity to variations in different parameters. Sensitivity analysis can be used to systematically explore the impact on model dynamics and results of varying each parameter value. Sensitivity analysis can therefore provide a framework for determining the relative importance of each parameter on model predictions and this may be used to direct measurement and subsequent analyses. This process is particularly challenging where there are large numbers of multi-valued parameters which would require a large number of test cycles if treated independently. There is therefore in general a need to use a method such as Taguchi analysis [67] to enable the parameters to be grouped to reduce the number of simulations required to determine the sensitive parameters in any model.

Moreover, in a multi-variable problem it may, depending on the nature of the problem, be possible to treat the individual variables as independent for the purpose of evaluation. However, for the great majority of systems, such independence cannot be assumed but must be demonstrated. This can often be a complex problem in its own right, since the model may be sensitive to dependencies among parameters and more complex sensitivity analysis techniques may be required. One such technique would be global sensitivity analysis [68], which allows assessment of the sensitivity of the model to parameters derived from informed combinations of values for those parameters. In the documentation provided detailing both the proposed work and the work undertaken we find no evidence of any sensitivity analysis having taken place.

15.3.4 Model Constraints

In a broad sense there are two main modelling strategies to be adopted in relation to problems of the type under consideration here. These are:

- a coarse granularity model which in this case would mean that patients are treated as a group whose characteristics are modelled as being representative of the population as a whole;
- a fine granularity model which in this case would mean that patients would be modelled on an individual basis with individual characteristics.

In this case the strategy chosen was based on a coarse granularity model with a time frame initially of 1 day. This meant that variations in factors such as the time of day at which patients presented and the potential impact on the time required for the test results to obtained were difficult to include within the model. It does however mean that the run time for the model was very short at around 2 minutes, making it suitable for desktop manipulation and analysis.

Because of the nature of the modelling tool chosen, various statistical process were necessary to enable variations such as the numbers of individuals classed as carriers to be identified and to track numbers downstream of admissions as they pass through the hospital.

The alternative fine granularity model would have been based around determining the characteristics of individual patients as they presented and would have allowed for a much reduced time frame from the 1 day of the model chosen. This would have supported an ability to assess factors such as the time of day of presentation of the returning of scan results or the loading on the laboratories to be included. Section 2, Model Architecture, explores further the impact of the modelling strategy chosen on both ease and transparency of implementation.

15.3.5 Documentation

In the report of the 4 December 2009[1] it is stated that 'in certain aspects the model is not an accurate representation of what is really happening'. The reasoning behind this statement is not fully established. There is, however, an implicit account of some of the mismatch between model and reality in terms of the changes required and these are set out in subsequent sections. Section 2, Model Architecture reviews these changes.

In particular, it was acknowledged that certain assumptions made when initially setting up the model, as for instance that all patients arriving at a general ward had an identification status with regard to MRSA. It was also established that there needed to be a probabilistic element with respect to the time taken to return test results when it was found that

1 *Summary of work updating the MRSA model in light of preliminary findings of pathfinder study*, author Jasper Taylor, Simulistics Ltd.

the distribution 'actually forms a bell curve with a long tail to the right.' This led to the conclusion that 'the value used in the model need no longer be a whole number of steps, so the mean turn-round time can be set to exactly the measured value.' This in turn suggests a requirement for a finer granularity within the model in respect of the time steps used.

Similarly, assumptions regarding length of stay (LoS) in hospital (initially set at 2 days) proved to be invalid with studies showing mean values for LoS of 0.4 days, 0.7 days and 1.5 days for 2 general hospitals and a tertiary referral hospital respectively. This was allowed for within the 1 day time frame by adding additional pathways to the model to allow a patient to move through from admission to a ward more rapidly than in the original model.

Other changes to the model format, within the constraints imposed by the Simile tool, included:

- using a different representation for patient populations when in hospital and when in the general community;
- changing the approach to handling the use of isolation wards to include more probabilistic elements and introducing a degree of randomness into this;
- replacing the 'conveyor-belt like' implementation to one which included probabilistic elements.

Finally, the document acknowledges that a shorter time step would perhaps have been more appropriate.

15.3.6 Nature of the data

Data, its structure and robustness is a key element of any modelling process as it is the quality of the input data that determines the quality of the outcomes. In the case of the model as described, it would appear that source data was in the process of being collected while the model was under development, resulting for instance in the changes to the assumption of the length of stay in hospital referred to under Section 1.5 above. While it is not unusual for certain data to be undefined at the start of a modelling process, it would seem that in this instance certain core data was not available when the model was being defined and developed. Certain of this is acknowledged in the document Proposal for work updating the MRSA model in light of preliminary findings of pathfinder study[1] in the section detailing the proposed changes to the model.

We recognise that the utility of the model has been to provide a descriptive platform for comparative reporting of different screening strategies. In light of the above, the fact that information on the system that the model was intended to represent was being generated while the model was under development raises some queries about the validity of the outcomes as providing other than an indicator of the possible economic impact of the

1 Dated 20 March 2009, author Jasper Taylor, Simulistics Ltd.

various strategies and thus should not be considered as a definitive study. However, while in this context the model may not be considered predictive so as to inform effective decisions regarding future process enhancements, it nevertheless can be considered as having been extremely valuable in supporting a greater understanding of the nature of the problem than had been the case when the project started.

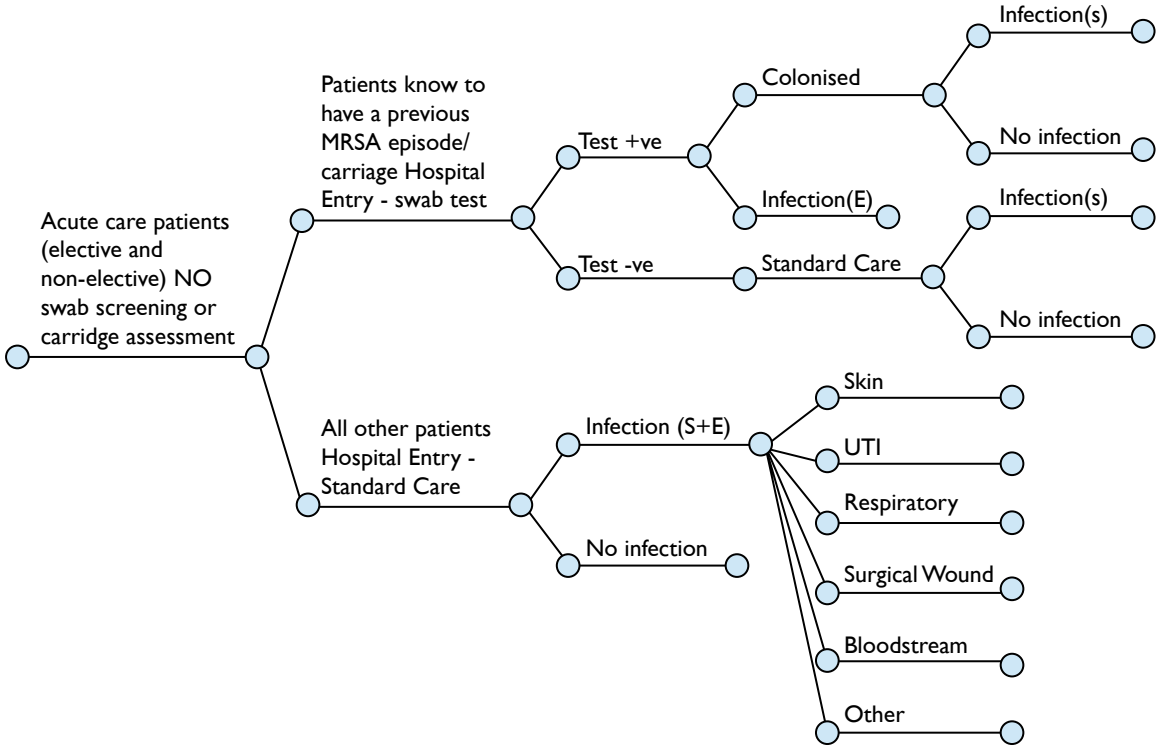
In order to progress to the next stage, that of developing a more effective, predictive model that incorporates the lessons learned from the current project, it is a necessary requirement to review not only the present model but the care data on which any new model is to be based. This should in turn lead to the definition of a model which is both more flexible and more structured towards the problem than is the case with the current model. As the 4 December 2009 document itself acknowledges *'It would then be possible to have different groups of patients within a ward, or groups of patients spanning multiple wards, behave in accordance with the norms of what they are being treated for as well as responding to the immediate environment in which they were treated. But this probably belongs in the specification of a completely new model.'*

15.3.7 Methodology Summary

It would seem that the methodology chosen for the development of the model concept was a standard approach which emphasised the clinical aspects of the process. In this case, it would have seemed appropriate to have supplemented this by a formalised approach to the development of software systems integrated within the ECHTA structure. Once the decision had been made to use a coarse granularity model, this impacted on the way in which the solutions could be implemented using patient distributions related to the population as a whole. It also perhaps resulted in a situation in which the sub-division of the patients into what appear to be crisp sets where a more fuzzy distribution might be more representative.

In this context, an approach based on a decision tree such as that shown in Figure 15-3 for strategy 1 above and taken from the document Development of economic model for HTA on screening for MRSA could form the basis of the definition of individual patients on presentation at the hospital. Once the individual patient has been identified, their progress can be tracked throughout their stay in hospital. In our recommendations for future work (Section 3), we propose.

Figure 15-3: Decision tree structure associated with Strategy 1



15.4 Model Architecture

15.4.1 Existing model

The model is structured into a series of interconnected sub-models and the graphical nature of the chosen modelling language makes these readily identifiable. The sub-models of Community, Pre-admission Clinic, Emergency Admission, Specialty Wards and Emergency Wards. These are sensible components and, again, the diagrammatic notation makes it easy to see the interconnecting flows between any two sub-models. Additionally, input parameters and output values were defined and distinct to model operation.

In order to understand the changes made to the existing model, it was necessary to understand that model and this required familiarisation with all existing documentation. Generally, there were good linkages between the documentation and model architecture. In some cases it was necessary to track through in detail the flows in the model to understand properly the architecture and this was eased by most nodes having a brief comment and / or name that indicated its function.

Overall, both the model and its documentation were of an appropriate standard. However, for some aspects the model formulation was particularly convoluted. For example the specialty ward processes and the interfacing between the specialty ward and the disease chooser are particularly hard to follow. It is important to note that this is not really down to the documentation; indeed there is effort made to explain these components. The underlying problem in these particular areas is the choice of granularity of representation and modelling language.

As noted in Section 15.3.5 the model aggregates individuals within the patient population into groups, i.e. Simile compartments, rather than considering those individuals as discrete entities. The compartment approach lends itself well to populations with limited variation among individuals, and so for example in the Community sub-model this works well: there are four compartments and flows between these and out into other model parts are clear. In contrast, the number of compartments and flows between those compartments in the Specialty Ward sub-model are less transparent. This is due to the number of different states any one patient can be in while in a Specialty Ward and, when this is scaled up across the number of Specialty Wards represented in the model, analysis becomes very difficult.

Additionally, while diagrams within Simile are appropriate for describing overall architecture complex, nested data structures are not well supported by the Simile interface. For example, the Admission selector is based on abundances of patients in different categories and those categories are stored as nested arrays. While the underlying operation of this is not complex in itself the description is hard to follow as it does not tie in well with the visual model description in Simile. Extended comments would have been helpful here.

In summary, the model architecture is a good representation of the key components of the system and in most cases the structure of the model is transparent and sensible. This architecture is well supported by the choice of a compartment-based development language. However, in the small number of cases where there is a need to increase resolution to distinguish among patient types the developers are required to trade this transparency off against increased resolution and the underlying architecture becomes more obscure.

15.4.2 Model revisions

The model has been enhanced to reflect new knowledge emerging from an additional study relating to the patient journey. The changes seek to increase the level of realism in representing patient flow through the hospital. In the documentation, changes are categorised as major and minor, and these are considered separately here. Again, these changes relate to the need to accommodate more detail in terms of individuals and their journey through the hospital than in the original model and to improve the treatment of temporal aspects of the system. Major changes are:

- presence of pre-identification patients in general wards;
- use of probabilistic turn-around time;
- categorisation of pre-identification patients;
- probabilistic length of stay in emergency receiving ward;
- simplification of handling strategy;
- first-in first-out operation of isolation rooms.

Minor changes to the model are:

- explicit burn-in time;
- addition of time-to-swab;
- addition of compliance test;
- having only one emergency ward;
- change interpretation of length of stay.

15.4.3 Major revisions

Presence of pre-identification patients in general wards

An assumption in the original model was that all patients arriving to general wards had an identification status. In terms of the model this meant that patients flowed from the Community sub-model through either the Pre-admission Clinic sub-model or the Emergency Admissions sub-model. From the results of the pathfinder study it was clear that patients can arrive from the community to general wards without an identification status.

In the revised model there are now clear routes for patients from both high-risk and low-risk categories from the Community to the Specialty Ward, via the relevant Disease Chooser, with probability of this occurring specified in a parameter. This is in addition to those patients referred to the Pre-Admission Clinic who do not get swabbed.

The manner in which this addition is made is sensible and clear from the model architecture. There are no significant ramifications to that architecture, as the addition of new pathways is transparent in the diagrammatic representation. Note that some initial testing to ensure that this had no undesired impact on overall model operation could be achieved easily by setting the proportion screened at pre-admission parameter to 100%.

Use of probabilistic turn-around time

In the original model, the number of time steps between patient arrival and the result of a screening test was fixed, at either 1 or 2 days, depending on the test used. This required historical tracking of patients, using time-dimensioned arrays to implement a queue of pre-test patients that are processed based on the individual arrival time at a rate determined by the test result time.

In the revised model the implementation adopts a probabilistic approach, such that at every time step a particular proportion of those patients receive results. This implementation removes the need for the time-dimension array. The input parameters that define time to swab and swab delay are combined into a swab result time parameter, and this is factored into the equation set that determine the waiting time for patients in different categories. This seems an appropriate implementation, although there is no real detail provided on the distribution of results obtained from the binomial distribution for different values of the swab result time parameter.

The documentation clearly states that the observed functional form of the distribution of waiting times is a "bell curve with a long tail to the right". While there is an implementation of distribution of waiting times in the model, instead of a mean value, this distribution is in the form of an exponential decay. It is not clear why there is a mismatch in this density distributions, and we are left to assume this is a limitation of the development environment. The documentation also states that non-whole number values may used in the model and, while we agree with this, the actual number of time steps that a test result takes in the model is always at least one day and must be rounded to the nearest day regardless of the functional form. This limitation is acknowledged by the developers (see Section 15.3.4).

Categorisation of pre-identification patients

The introduction of the direct flow from Community sub-model to the Disease Chooser sub-model means that patients may arrive at the Disease Chooser sub-model without any identification status. The Disease Chooser allocates patients into categories and so a new category has been created "NoInfo". The Equation List in Simile provides information on the enumerated types included in the model and this new category is present. Further, it is implemented at the flow point into the Disease Chooser sub-model and this is located at a suitable position in the model.

Again, the enumerated type addition is present in the model, and the implementation in the model may be traced. This implementation is associated with the interface between the two most complex compartments, Specialty ward and Emergency ward. We agree that defining a new enumerated type, while increasing local complexity of the model, reduces the need to represent this information across a large number of pathways. For both enumerated types, should data be available on the relative balance of patients among these categories these are readily included in the model.

Probabilistic length of stay in emergency receiving ward

The introduction of a probabilistic length of stay in the Specialty ward meant that waiting times for results were handled differently in each of Specialty and Emergency wards. The documentation states that implementation of a probabilistic turnaround time in the Emergency ward was then necessary for the sake of consistency. We would prefer the term desirable to necessary. More importantly, the desire to accommodate a probabilistic treatment should be motivated by the address of any shortcomings associated with a deterministic treatment.

The shortcoming identified by the developers will indeed be eased, but not wholly resolved, using a probabilistic turnaround time. We assume again that if data exists for the Specialty wards this same data exists for Emergency wards and this may be included in the form of the probability density distribution from which turnaround times may be sampled.

Note, due to the complex network of flows, variables and compartments it is difficult, without a more abstract, layered representation of the model, to assess the extent to which the Emergency ward is a simplified Specialty ward. The underlying architectures are similar however and there is no reason to believe this is not the case.

Simplification of handling strategy

We agree that Strategies 3-5 may be implemented with minor and localised impact to the model architecture. Likewise, implementation of Strategy 6 would indeed require a more substantial change to this architecture, although its implementation is in no way precluded by the enhancements implemented in the revised model.

First-in first -out operation of isolation rooms

The desire to modify the model to implement a first-in first-out management of isolation rooms illustrates the trade-off between model simplicity and model flexibility. It is clear from the documentation, and the constraints introduced by compartment-based modelling, that to revise the model to accommodate this management scheme would require a cumbersome implementation based on complex time-dimensioned data structures describing the historical attribution of isolation rooms to patients. The revision exploits Simile's population sub-model feature, and the coupling of this sub-model to the Specialty ward sub-model is clear in the model architecture.

This coupling is in the form of five channels - three input (isolated colonised, uncolonised, infected) and two output (bumped (removed from isolation due to capacity constraints) and dis (discharged)). This coupling seems appropriate given that the input is driven by the existing model and the output by the set of possible outcomes to a patient in isolation. While the documentation could have been much fuller for this revision but the underlying queueing system is evident. This system made more cumbersome than it needs to be by the development tool but the concept is sensible. The mixed mode operation (new and old model implementation) is a useful provision as it is then possible to compare the impact of first-in first-out under different population distributions, hospital settings and colonisation pressures.

15.4.4 Minor revisions

Explicit burn-in time

The initial set-up of any model is known to impact on results and so it is common practice to run models for a length of time in order that the population reaches steady state before any experimentation and analyses. Here, the burn-in time is a numerical value, to be selected by the user, and prior to that burn-in time the system has no capacity for isolation or decolonisation. This lack of capacity is effected by zero values for the relevant parameters until after the burn-in period. In principle this seems a simple and reasonable approach. However, two aspects have not been described in the documentation. First, there is no indication as to how long this burn-in period should be for the revised model; in the original model it was 1,800 time steps. Second, the approach introduces an abrupt shift from zero to full capacity for isolation and decolonisation and there is no sense of how sensitive the model is to such an abrupt shift and whether there is a further transient in the system dynamic following the end of the burn-in time.

Addition of time-to-swab

This new parameter reflects the decision to increase the resolution of the turnaround time for test results. There is a clear link between observational data, detailed elsewhere in the overall project documentation, and the model parameter.

Addition of compliance test

This is a necessary set of parameter to reflect the overall objective of better reflecting the patient pathways, in particular where patients do not get swabbed. The implementation is clear and appropriate; the documentation does not comment that this data was available but should it be the model is readily amenable to parameterisation.

Have only one emergency ward

Given that the hospitals considered in the study only had one emergency ward this change seems most appropriate.

Change interpretation of length of stay

The documentation indicates that data exists for length of stay in emergency wards and, separately, specialty wards. The documentation is ambiguous but it appears to suggest that the model considered length of stay for the specialty ward and, where appropriate, added on an (extra) value for emergency stay. For reporting on speciality length of stay, a calculated average emergency length of stay is now removed, implying it was not before. In any case there is no underlying data. This text is difficult to interpret but we assume a bookkeeping change has been made to improve transparency in reporting.

15.4.5 Further improvements

The final section of the documentation supplied considers developments that would be undertaken in the next phase of development. This is a useful critque of the revised model and extensions focus on increasing granularity of the system representation in both time and space.

The model has one day as its minimum time step and because this is coarser than the differences among treatments the time step then introduces a bias in the results. The developers make efforts to work round this limitation to best accommodate knowledge of test result times and patient pathways, but it is noted that to increase the temporal resolution is a major undertaking. We agree that on a local scale, i.e. specific equations, this is trivial and the developers present an outline solution to one equation type used. However, as the developers note, to ensure that all model components are operating in line with the new time step is labour intensive. Clearly a shorter time step would accord better with available data.

While less documentation text is devoted to the issue of space, this is a more substantial aspect. As noted previously, the model aggregates patients into high and low risk categories and so assumes homogeneity in risk levels among patients in any ward. More than this, there is a direct mapping from ward to specialty, rather than specialties mixing across wards,

and patients within specialty are also considered homogeneous with respect to risk level. As with temporal resolution, there is a work-around presented but an account of such fine-grained patient categories and ward-specialty intermixing is not readily supported by compartment-based modelling.

15.5 Commentary and recommendations

Based on the above it is clear that the model as developed has partly fulfilled it original intent of isolating and identifying the economics of the different testing strategies for MRSA. The model is a descriptive tool able to compare, under stated assumptions, the costs of different strategies. Additionally, it can be said that the model has served as an effective tool in increasing the understanding of the nature of the problem, the system level and operational constraints involved, baseline results and the nature and sources of the core data. This includes the need to be able to reflect the situation at the level of an individual hospital in order to reflect the characteristics of that hospital, as for instance in relation to location and patient base, and its patient mix. Working from this base it should be possible to define the requirements and specifications for a next generation model which will, when combined with current system understanding and data sources, provide a predictive framework to support and decision making in relation to screening strategies and other related policies.

We recommend a modelling strategy that is able to:

- predict the impact of screening and other costed management strategies on prevalence of HAI;
- direct investment of observational studies to target sensitivities in data, i.e. measurements ofmost importance, identified by the model;
- incorporate existing knowledge, including uncertainties in that knowledge, and accommodate new data as and when it becomes available;
- represent the system in terms of the range of components and processes that determine patient flow and care events through a hospital;
- represent individual patients and carers, to provide variation among individuals in terms of their characteristics and to link these to observed patient and carer data;
- provide an explicit account of space, such that patient and carer cohorting strategies together with different ward configurations and bed occupancy profiles, such that the impact on prevalence of different policies may be determined.

To meet this requirement list, we suggest that the hospital and the community it supports be described as a complex system. Complex systems comprise a large number of interacting components and the system behaviour arises as a consequence of interactions among those components [69]. Agent-based modelling provides a computational framework within which individual components may be modelled as discrete entities with potentially unique characteristics and behaviour [62].

Moreover, agent-based models support an explicit account of space [70], and time steps may be characteristic of the problem considered [71]. Finally, because the agents in the system may be constructed to represent observed components of the real system and because measurable characteristics may be ascribed to those components, agent-based models provide a mechanism for directly parameterising modelled components with real-system measurements [72], and this is essential if models are to be parameterised by real data and the results used to manage that system.

In summary, we believe that, given the modelling work undertaken to date combined with the knowledge and data derived from the pathfinder study, this is an opportune moment to undertake this kind of agent-based modelling. Existing work already provides the underlying model architecture in terms of key pathways and system processes, and a large body of observational data would support agent-based model parameterisation. This would provide a platform for developing a more complex, powerful tool for predictive modelling to inform decisions on costed management of HAI.

16 Acronyms

Acronym	Expanded Acronym
A & E	Accident and Emergency
CCU	Coronary Care Unit
CDC	Centre for Disease Control (US)
Chrom	Chromogenic Agar
CLO	Central Legal Office
ENT	Ear Nose and Throat
HDU	High Dependency Unit
HTA	Health Technology Assessment
ICU	Intensive Care Unit
IQR	Inter Quartile Range
ISD	Information and Statistics Division
LIMS	Laboratory Information and Management System
LOS	Length of Stay
MIPS	Median Index of Public Sector Building Tender Prices (MIPS) Index
MRSA	Meticillin Resistant *Staphylococcus aureus*
NHS	National Health Service
NHS QIS	NHS Quality Improvement Scotland
PCR	Polymerase Chain Reaction
SGHD	Scottish Government Health Department
SIPC	Standard Infection Prevention and Control
TAT	Turn Around Time

17 Glossary

Acute hospital: Hospitals in Scotland are classified as acute hospitals and non-acute hospitals. Acute hospitals were defined using the classification proposed by ISD. Acute hospitals provide a wide range of specialist care and treatment for patients. Typically, services offered in the NHS acute sector are diverse. They include: consultation with specialist clinicians (consultants, nurses, dieticians, physiotherapists and a wide range of other professionals); emergency treatment following accidents; routine, complex and life saving surgery; specialist diagnostic procedures; and close observation and short-term care of patients with worrying health symptoms.

Admission: Occurs when an inpatient occupies an available staffed bed in a hospital and remains overnight whatever the original intention. See Inpatient definition for more details.

Admission screen: Left and right nostrils using a single nasal swab, this will be undertaken by hospital staff on or as soon after admission as is possible according to local protocols.

Admission types – emergency or unplanned: For clinical reasons, a patient is admitted at the earliest possible time, usually immediately, after seeing a doctor - the patient will not necessarily be admitted via an accident and emergency department.

Admission types – routine, planned or elective: All admissions where the patient is admitted as planned are termed "routine". In most cases patients are admitted directly from their home for inpatient or day case treatment following a period on the waiting list.

Anterior: Situated before or towards the front.

Antibiotic: A substance that kills or inhibits the growth of bacteria. They are used to treat or prevent infection.

Antimicrobial: A general term that covers all medicines that kill or inhibit the growth of microorganisms such as bacteria, fungi or viruses.

Antiseptic: A substance that inhibits the growth and survival of microorganisms that is usually only applied externally.

Assessment: A scientific process of examining and reporting properties of a technology used in health care, such as safety, efficacy, feasibility and indications for use, cost and cost-effectiveness, as well as social, economic and ethical consequences.

Audit: The process of setting and adopting standards and measuring performance against those standards with the aim of identifying both good and bad practice.

Bias: In general, any factor that distorts the true nature of an event or observation. In clinical investigations, a bias is any systematic factor other than the intervention of interest that affects the magnitude of (i.e. tends to increase or decrease) an observed difference in the outcomes of a treatment group and a control group. Bias diminishes the accuracy (though not necessarily the precision) of an observation. Randomization is a technique used to decrease this form of bias. Bias also refers to a prejudiced or partial viewpoint that would affect someone's interpretation of a problem. Double blinding is a technique used to decrease this type of bias.

Boarder: A patient who is under the care of a specialty not usually attendant on the ward.

Body site: Area of the patients' body where a swab sample is taken from.

Capture rate: The proportion of patient admissions who are screened compared with the total number of admissions.

Clinical effectiveness: The extent to which a specific intervention, procedure, regimen, or service does what it is intended to do under ordinary circumstances, rather than controlled conditions. Or more specifically, the evaluation of benefit to risk of an intervention, in a standard clinical setting, using outcomes measuring issues of importance to patients (e.g. ability to do daily activities, longer life, etc.).

Clinical governance: Ensures that patients receive the highest quality of care possible, putting each patient at the centre of his or her care. This is achieved by making certain that those providing services work in an environment that supports them and places the safety and quality of care at the top of the organisation's agenda. Management of clinical risk at an organisational level is an important aspect of clinical governance. Clinical risk management recognises that risk can arise at many points in a patient's journey, and that aspects of how organisations are managed can systematically influence the degree of risk.

Clinical pathway: A multidisciplinary set of daily prescriptions and outcome targets for managing the overall care of a specific type of patient, e.g. from pre-admission to post-discharge for patients receiving inpatient care. Clinical pathways often are intended to maintain or improve quality of care and decrease costs for patients in particular diagnosis-related groups.

Cohorting: Patient is placed in a room and cared for by dedicated nursing staff along with other patients who are (in the context of this programme):

a. known to be MRSA colonisation positive due to admission test result.
b. known to be MRSA colonisation positive due to pre-assessment clinic test result.
c. known to be MRSA infection positive as a result of a laboratory confirmed infection.
d. known to be MRSA positive from a previous MRSA positive result (pre-emptive isolation until shown to be negative by appropriate screen result).

Cohorting can be undertaken for any other pathogen not just MRSA. Cohorting should be undertaken according to the HPS infection control Contact Precautions Policy and Procedure see http://www.hps.scot.nhs.uk/haiic/ic/guidelinedetail.aspx?id=37303.

Cohort study: An observational study in which outcomes in a group of patients that received an intervention are compared with outcomes in a similar group i.e. the cohort, either contemporary or historical, of patients that did not receive the intervention. In an adjusted- (or matched-) cohort study, investigators identify (or make statistical adjustments to provide) a cohort group that has characteristics (e.g. age, gender, disease severity) that are as similar as possible to the group that experienced the intervention.

Colonisation: MRSA is present on any body site without causing any infection or adverse effect to the individual.

Community acquired MRSA: Describes a number of strains of MRSA which are seen in individuals who would not normally be expected to acquire MRSA. These strains can both colonise and/or infect patients. These strains are found in patients who have not recently been in hospital, undergone surgical procedures or prolonged treatment with antibiotics. They are associated with individuals who have close living and physical contact with others. E.g. athletes involved in contact sports. Some countries have seen these strains with hospitals. Not all MRSA strains are clearly categorised in CA-MRSA and HA-MRSA.

Community associated MRSA infection: A laboratory confirmed MRSA positive clinical sample is taken <48 hours after admission and patient shows signs or symptoms according to CDC infection criteria. This will include all MRSA strains regardless of where it was acquired. The definition relates to the location where the infection became prevalent.

Consent: If a patient agrees to have a nasal swab taken in a pre-assessment clinic or on admission implied consent is given. Patients are free to decline consent. This must be recorded as an indicator of acceptability of the nasal screening process. If a patient is unable to give consent, pathfinder hospitals should follow local policy.

Contact precautions: Techniques used in infection prevention and control to prevent person to person contact and spread of pathogens.

Control (s):

1. [In a controlled trial:] A participant in the arm that acts as a comparator for one or more experimental interventions. Controls may receive placebo, no treatment, standard treatment, or an active intervention, such as a standard drug.
2. [In a case-control study:] A person in the group without the disease or outcome of interest.
3. [In statistics:] To adjust for, or take into account, extraneous influences or observations.

Cost-benefit analysis: A comparison of alternative interventions in which costs and outcomes are quantified in common monetary units.

Cost-consequence analysis: A form of cost-effectiveness analysis in which the components of incremental costs (of therapies, hospitalization, etc.) and consequences (health outcomes, adverse effects, etc.) of alternative interventions or programs are computed and displayed, without aggregating these results (e.g. into a cost-effectiveness ratio).

Cost effectiveness analysis: A comparison of alternative interventions in which costs are measured in monetary units and outcomes are measured in non-monetary units, e.g. reduced mortality or morbidity.

Critical appraisal: The process of assessing and interpreting evidence by systematically considering its validity, results and relevance.

Day case: A patient who makes a planned attendance to a specialty for clinical care sees a doctor or dentist or nurse (as the consultants' representative) and requires the use of a bed or trolley in lieu of a bed. The patient is not expected to, and does not, remain overnight. Many of these patients require anaesthesia. (These patients are excluded from the pathfinder project)

Decolonisation: Treatment designed to reduce the burden of MRSA colonisation on a patient known to be MRSA positive. This will be undertaken according to local protocols for decolonisation.

Deferred admission: Patients who, when first placed on a waiting list, were under either social or medical constraints which affected their ability to accept an admission date if offered. Examples specific to this programme are: Patients who are not medically ready for admission, due to a condition other than that requiring treatment, where the time taken to become medically fit would delay admission relative to the normal waiting time for that treatment, e.g. a hip replacement which is delayed because the patient is considerably overweight; an operation which is delayed because the patient is found to have a heart arrhythmia which needs treating by a Cardiologist or a patient for whom it is considered better to attempt decolonisation of MRSA carriage before their planned procedure is undertaken.

Deferred admission: Patients who, when first placed on a waiting list due to either MRSA screen or infection a decision has been made to delay their admission due to their MRSA status.

Discharge: An inpatient discharge marks the end of an inpatient episode of care and occurs when the patient:

- Is discharged to a location external to the NHS.
- Is transferred to another NHS hospital.
- Dies.

Hence inpatient discharges include deaths and inpatient transfers-out.

Economic evaluation: The comparative analysis of alternative courses of action, in terms of their costs and consequences.

Economic model: In healthcare, a mathematical model of the patient pathway that describes the essential choices and consequences for the interventions under study and can be used to extrapolate from intermediate outcomes to long-term outcomes of importance to patients.

Elective or planned admission: A patient who has been admitted at a pre-arranged time for a planned procedure. Elective patients attending a pre-assessment clinic should have had a swab taken at the clinic and undergone a decolonisation procedure before admission and MRSA status should be known on admission. Elective patients not attending a pre-assessment clinic should be screened on admission.

Emergency or unplanned admission: A patient who has been admitted without a pre-assessment appointment. These patients will include urgent GP referrals, accident and emergency patients, clinical referrals.

Empirical: Empirical results are based on experience (or observation) rather than on reasoning alone.

Endemic: Something peculiar to a particular people or locality, such as a disease which is always present in the population.

Endemic MRSA: Describes the strains of MRSA which is present within the population.

Epidemic MRSA (EMRSA): A level of MRSA in the population which is significantly greater then usually present over a short period of time.

Epidemiology: The study of the occurrence, distribution and control of infectious and non infectious diseases in populations. This is a key part of public health medicine.

Equilibrium colonisation rate: A rate of spread at which the overall level of colonisation in a population stays the same.

Evaluation research: Various research methods that are used to assess a program, agency, policy, etc., particularly with respect to elements such as organization, processes, outcomes and utility.

Formative evaluation: An ongoing review to describe and analyse how an activity is carried out and to interpret the outcomes. It is valuable in helping those directly involved in the activity to assess its strengths and weaknesses and the changes required to improve its effectiveness.

GROS General Register Office for Scotland: Part of the devolved Scottish Administration. It is responsible for the registration of births, marriages, civil partnerships, deaths, divorces, and adoptions. It runs the Census and uses Census and other data to publish information about population and households. It is the main source of family history records.

Guidelines: A systematically developed statement to assist practitioner and patient decisions about appropriate health care for one or more specific clinical circumstances. The development of clinical practice guidelines can be considered to be a particular type of HTA; or, it can be considered to be one of the types of policymaking that is informed or supported by HTA.

Hospital Associated MRSA infection: A laboratory confirmed MRSA clinical sample is taken >48 hours after admission and patient shows signs or symptoms according to the CDC Nosocomial infection definition criteria.

Healthcare Associated MRSA infection: An MRSA infection which is generally associated with healthcare, but not necessarily attributed to a particular hospital admission.

Health Protection Scotland (HPS): Health Protection Scotland (HPS) was established by the Scottish Government in 2005 to strengthen and co-ordinate health protection in Scotland. HPS plan and deliver effective and specialist national services which co-ordinate, strengthen and support activities aimed at protecting all the people of Scotland from infectious and environmental hazards. This is done by providing advice, support and information to health professionals, national and local government, the general public and a number of other bodies that play a part in protecting health. Website address: http://www.hps.scot.nhs.uk/

HEAT: Local Delivery Plans set out a delivery agreement between the Scottish Executive Health Department and each NHS area board, based on the key Ministerial targets. Local Delivery Plans reflect the HEAT Core Set - the key objectives, targets and measures that reflect Ministers' priorities for the Health portfolio. The key objectives are as follows:

- Health Improvement for the people of Scotland - improving life expectancy and healthy life expectancy;
- Efficiency and Governance Improvements - continually improve the efficiency and effectiveness of the NHS;
- Access to Services - recognising patients' need for quicker and easier use of NHS services; and
- Treatment Appropriate to Individuals - ensure patients receive high quality services that meet their needs.

High risk specialties: Specialties within which admitted patients are considered to be exposed to a high level of risk of contracting an MRSA infection or treat more vulnerable patients.

Incidence: The number of new cases of an illness in a defined population during any defined period.

Incremental cost effectiveness ratio: The additional cost of the more expensive intervention as compared with the less expensive intervention divided by the difference in effect or patient outcome between the interventions, e.g. additional cost per QALY.

Infection prevention and control measures: These include isolating, cohorting and decolonisation where appropriate, with the ultimate aim of minimising the risk of patients infecting themselves or infecting/colonising others as a result of their colonisation status.

Inpatient: Patients who are admitted to an acute speciality and who stay overnight. These patients would be included in ISD overnight returns.

Internal validity: The extent to which the findings of a study accurately represent the causal relationship between an intervention and an outcome in the particular circumstances of that study. The internal validity of a trial can be suspect when certain types of biases in the design or conduct of a trial could have affected outcomes, thereby obscuring the true direction, magnitude, or certainty of the treatment effect.

Invasive devices: Any device which temporarily is inserted into the body. These include: peripheral vascular catheters (PVCs); central vascular catheters (CVCs); urinary catheters; and ventilators.

Isolation: Patient is placed in a single room with hand washing facilities, ideally with en-suite toilet and shower where available. Isolation should be undertaken according to the HPS Infection Control Contact Precautions Policy and Procedure see http://www.hps.scot.nhs.uk/haiic/ic/guidelinedetail.aspx?id=37303.

Likelihood ratio:

1. Compares the chance of positive (or negative) test results in those with the disease to the chance in those without the disease. The likelihood ratio for a positive test result is sensitivity/(1 minus specificity). The likelihood ratio of a negative test result is (1 minus sensitivity)/specificity.
2. A statistical indicator comparing the adequacy of two related models to data, allowing hypothesis testing in a large number of situations.

Low risk specialties: Specialties within which admitted patients are considered to be exposed to a low level of risk of contracting an MRSA infection. (See table 7)

Mean: The average value, calculated as the sum of all observed values divided by the total number of observations.

Median: The middle observation when data have been arranged in order from lowest to highest value.

Meticillin: An antibiotic related to the penicillin class used in the identification of MRSA.

Meticillin Resistant** Staphylococcus aureus **(MRSA): Strain of the bacterium *Staphylococcus aureus* which is resistant to the antibiotic meticillin.

MRSA infections: Infection will be defined as an MRSA positive sample and associated signs or symptoms according to the Centre for Disease Control (CDC) (Horan *et al* 2008) criteria. (See Appendix 3)

Meticillin sensitive** Staphylococcus aureus **(MSSA): Strain of the bacterium *Staphylococcus aureus* which is not resistant to the antibiotic meticillin.

Model: A simplified yet accurate representation of a program or intervention based on a set of assumptions.

Mupirocin: An antibiotic used in a nasal cream to decolonise patients colonised with microorganisms including MRSA from the nose.

Nares: Nostrils.

Negative predictive value: Is the proportion of patients with negative test results who are correctly diagnosed as negative.

NHS QIS: See NHS Quality Improvement Scotland.

NHS Quality Improvement Scotland (NHS QIS): NHS QIS was established in 2003 and leads the use of knowledge to promote improvement in the quality of healthcare for the people of Scotland. It performs four key functions: providing advice and guidance on effective clinical practice; setting standards; driving and supporting implementation of improvements in quality; and assessing the performance of the NHS, reporting and publishing the findings.

In addition, NHS QIS also has central responsibility for patient safety and clinical governance across NHS Scotland. Website address: www.nhshealthquality.org.

NHS board: There are 22 NHS boards of two types: 14 territorial boards responsible for healthcare in their areas and eight special health boards which offer support services nationally.

Nosocomial MRSA Infections or Healthcare Associated MRSA Infections: A laboratory confirmed MRSA clinical sample is taken >48 hours after admission and patient shows signs or symptoms.

Opportunity cost: The amount that could be spent on alternative healthcare strategies if the health technology in question was not used.

Outcomes: Components of patients' clinical and functional status after an intervention has been applied.

Patient care pathway: A plan of care that outlines key activities within specified times. The pathway follows the patients' journey of care.

Patient journey: The pathway through the health services taken by the person who is receiving treatment, and as viewed by that person.

Peer review: The process by which manuscripts submitted to health, biomedical, and other scientifically oriented journals and other publications are evaluated by experts in appropriate fields (usually anonymous to the authors) to determine if the manuscripts are of adequate quality for publication.

Personal protective equipment (PPE): Items as gloves, gowns, medical masks, or eye protection (such as a face shield, goggle, or visor).

Point Prevalence: The ratio of the total number of cases of an event in a population at a particular point in time compared with the total population at the same point in time.

Policy: The highest level statement of intent and objectives within an organisation. A policy can also be a required process or procedure within an organisation.

Polymerase chain reaction (PCR): A laboratory method for detecting the genetic material of an infectious disease agent in specimens from patients. This type of testing has become an essential tool for detecting infectious disease agents.

Population register: A data collection system in which characteristics of all or part of a population are recorded over time.

Positive predictive value: Or precision rate, or post-test probability of disease, is the proportion of patients with positive test results who are correctly diagnosed as positive. It is the most important measure of a diagnostic method as it reflects the probability that a positive test reflects the underlying condition being tested for. Its value does however depend on the prevalence of the disease, which may vary.

Post decolonisation test: MRSA screening for decolonisation should take place at least 2 days after the cessation of the decolonisation treatment. This requires 3 sets of nasal swabs taken with at least two days elapsing between each sample being taken.

Pre-admission clinic: Clinic attended by patients prior to admission where they are screened for MRSA. This will include pre-admission clinics and outpatient clinics.

Pre-admission screening: This will be undertaken before patients are admitted.

Pre-emptive isolation: Where patients are known to have been MRSA positive previously and are isolated on admission.

Probability distribution: Portrays the relative likelihood that a range of values is the true value of a treatment effect (or other outcome or result). This distribution may follow the form of a particular function, e.g., a normal, chi square, binomial, or Poisson distribution. An estimate of the most likely true value of the treatment effect is the value at the highest point of the distribution. The area under the curve between any two points along the range gives the probability that the true value of the treatment effect lies between those two points. Thus, a probability distribution can be used to determine an interval that has a designated probability (e.g. 95%) of including the true value of the treatment effect.

Prospective study:

1. In evaluations of the effects of healthcare interventions, a study in which people are divided into groups that are exposed or not exposed to the intervention(s) of interest before the outcomes have occurred. Randomized controlled trials are always prospective studies and case control studies never are. Concurrent cohort studies are prospective studies, whereas historical cohort studies are not (see cohort study), although in epidemiology a prospective study is sometimes used as a synonym for cohort study.
2. A study in which the investigators plan and manage the intervention of interest in selected groups of patients. As such, investigators do not know what the outcomes will be when they undertake the study.

Protocol: The plan or set of steps to be followed in a study. A protocol for a systematic review should describe the rationale for the review; the objectives; and the methods that will be used to locate, select and critically appraise studies, and to collect and analyse data from the included studies.

Quality assurance (QA): Activities intended to ensure that the best available knowledge concerning the use of health care to improve health outcomes is properly implemented. This involves the implementation of health care standards, including quality assessment and activities to correct, reduce variations in, or otherwise improve health care practices relative to these standards.

Randomised controlled trials (RCT): An experiment of two or more interventions in which eligible people are allocated to an intervention by randomization. The use of randomization then permits the valid use of a variety of statistical methods to compare outcomes of the interventions.

Retrospective study: A study in which investigators select groups of patients that have already been treated and analyze data from the events experienced by these patients. Retrospective studies are subject to selection bias because investigators can select groups of patients with known outcomes or exposures or that are otherwise not truly representative of the broader population of interest. Case control studies are always retrospective, cohort studies sometimes are, randomized controlled trials never are.

Review: A review article in the medical literature which summarises a number of different studies and may draw conclusions about a particular intervention. Review articles are often not systematic. Review articles are also sometimes called overviews.

Risk: The risk is the ratio of people with an event in a group to the total in the group.

Risk assessment: The qualitative or quantitative estimation of the likelihood of adverse effects that may result from exposure to specified health hazards or from the absence of beneficial influences.

Risk factor: An aspect of a person's condition, lifestyle or environment that increases the probability of occurrence of a disease. For example, cigarette smoking is a risk factor for lung cancer.

Risk management: A systematic approach to the management of risk, staff and patient/client/user safety, to reducing loss of life, financial loss, loss of staff availability, loss of availability of buildings or equipment, or loss of reputation. Risk management involves identifying, assessing, controlling, monitoring, reviewing and auditing risk.

Screening: A public health service in which members of a defined population, who do not necessarily perceive they are at risk of a disease or its complications, are asked a question or offered a test, to identify those individuals who are more likely to be helped than harmed by further tests or treatment.

Selection: The non-random survival and reproduction of an organism which alters the frequency of occurrence of a particular gene and therefore trait in that organism.

Sensitivity: The ability of a test to detect a disease when it is present.

Sensitivity analysis: A means to determine the robustness of a mathematical model or analysis (such as a cost-effectiveness analysis or decision analysis) that tests a plausible range of estimates of key independent variables (e.g. costs, outcomes, probabilities of events) to determine if such variations make meaningful changes the results of the analysis. Sensitivity analysis also can be performed for other types of study; e.g. clinical trials analysis (to see if inclusion/exclusion of certain data changes results) and meta-analysis (to see if inclusion/exclusion of certain studies changes results) (INAHTA).

Separated: Patients who have the same MRSA status i.e. are:

a. known to be MRSA colonisation positive due to admission test result
b. known to be MRSA colonisation positive due to pre-assessment clinic test result
c. known to be MRSA infection positive as a result of a laboratory confirmed infection
d. known to be MRSA positive from a previous MRSA positive result (pre-emptive isolation)

Are housed within the same room as patients who are not MRSA positive but are separated by at least 3 feet from any adjacent persons by use of: cubicles or use of closed bed curtains. This is considered to be a step down from full cohorting. These patients do not have separate nursing staff.

Specificity: The ability of a test to indicate non-disease when no disease is present.

Standard operating procedure: Detailed, written instructions to achieve uniformity of the performance of a specific function.

Standard precautions: A group of infection prevention practices that apply to all patients, regardless of suspected or confirmed diagnosis or presumed infection status. Standard Precautions are a combination and expansion of Universal Precautions and Body Substance Isolation. Standard Precautions are based on the principle that all blood, body fluids, secretions, excretions (except sweat), non-intact skin, and mucous membranes may contain transmissible infectious agents. Standard Precautions include hand hygiene, and depending on the anticipated exposure, the use of gloves, gown, mask, eye protection, or face shield. Also, equipment or items in the patient environment likely to have been contaminated with infectious fluids must be handled in a manner to prevent transmission of infectious agents (e.g. wear gloves for handling, contain heavily soiled equipment, and properly clean and disinfect or sterilize reusable equipment before use on another patient).

Stochastic model: A model or equation that incorporates a random variable.

Summative evaluation: A review designed to judge the effectiveness of an activity in terms of its outcomes and impact. The focus may be on measuring outcomes and quantifying costs and benefits. It is often carried out at the end of a process.

Surveillance: The ongoing, systematic collection, analysis and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know.

Systematic review: A review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyse data from the studies that are included in the review.

Turnaround time: The time interval between taking the nasal swab until the result is reported on the laboratory system for action by the ward.

Universal screening: Every eligible patient admitted to the hospital in question is screened either before admission or on admission.

1. Originator's report number:	HPS/HAIIC/MRSA/2011/02/2
1a. Additional Report Number:	E.g. If published under EU contract
2. Publishers Name and Location:	National Services Scotland Health Protection Scotland Room, 1 Cadogan Square, Cadogan Street, Glasgow G27HF
3. Funding source and period covered:	SGHD HAITF Delivery Plan DELIVERY April 2008 to March 2011 AREA 4: GUIDANCE AND STANDARDS Item 4.3
4. Sponsor's Name and Address:	Nursing Advisor HAI Chief Nursing Officer Directorate St Andrew's House
5. Report Classification and Caveats in use	UNLIMITED
5a. Date written:	31 December 2009
5b. Date published	February 2011
5c. Pagination:	138
7a. Report Title:	NHS Scotland MRSA Screening Pathfinder Programme Final Report Volume 3: Staff Patient Acceptability 2010, Health Protection Scotland
7b. ISBN	978-1-873772-33-1
7b. Conference details (if part of conference then give conference particulars):	Not Applicable
7c. Part of Series	
7d Supersedes document	
7e Review date	
8. Authors:	MRSA Screening Programme Team
9. Descriptors/Key words should be terms from the HPS taxonomy	MRSA; Screening; Epidemiology; Statistics, Cohort Study, Healthcare; Healthcare Associated Infection; Infection Control, Scotland, Modelling, Economics

10a. Abstract : [Maximum 200 words]

The MRSA Screening Pathfinder Project implemented Universal Screening within three Pathfinder Health boards from August 2008 to July 2009. The development of, and results from, an economic model were described within the NHS Quality Improvement Scotland 2007 HTA report – The clinical and cost effectiveness of screening for meticillin resistant Staphylococcus aureus (MRSA). This cost consequence analysis model was presented with the costs of the different screening strategies and the number of infections avoided. Development of this model was constrained by the lack of robust evidence for key variables in the infection control literature. Many of the assumptions and parameters used in constructing the NHS QIS HTA model were not confirmed by the findings of the Pathfinder project. The model was re-worked, using observed data, in order to better represent the observations found in the Pathfinder Boards. The reworked model, populated with the parameters found within the pathfinder study, projected a reduction in MRSA colonisation over three to five years to low endemic levels. Little difference was seen in the modelled effectiveness of using PCR versus chromogenic agar over this time frame.

Authorisation *(complete as applicable)*

Role		**Name**
Head of Division/ Delegated owner	Mary Morgan	
Lead Consultant	Prof. Jacqui Reilly	
Project/Programme Manager	Sally Stewart	
Document Business Classification	Active Projects and Programmes, Healthcare Associated Infections and Infection Control, Epidemiology and Statistics,	