Scottish Hospital Standardised Mortality Ratio
2015 Model Review & Discussion Paper

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Executive Summary

The Scottish Patient Safety Programme (SPSP) was established with the overall aim of reducing hospital mortality by 15% by 2012. This was then extended to a 20% reduction by December 2015. Since December 2009, Information Services Division (ISD) has published quarterly Hospital Standardised Mortality Ratios (HSMR) for all Scottish hospitals participating in the SPSP. The current HSMR model methodology will therefore continue to be used until data covering the period up to December 2015 is published at the end of May 2016, after which ISD recommends updating the HSMR model methodology as described in this report, this includes:

- Re-basing the model on a more frequent basis. This will ensure that the predicted mortality used within the HSMR calculation is based on more up to date data.
- Updating Charlson Index weightings used to calculate co-morbidity & prior morbidity weightings.
- Updating the primary diagnosis groupings using the 140 Clinical Classification System (CCS) categories as used in the Summary Hospital Mortality Indicator (SHMI) produced by the Health & Social Care Information Centre (HSCIC).
- Adding co-morbidities and Scottish Index of Multiple Deprivation (SIMD) to the explanatory variables used for case-mix adjustment.
- Moving to using a logistic regression based model instead of a decision tree.

Following the last publication of the HSMR using the current methodology in May 2016, ISD propose continuation of a written quarterly publication alongside an interactive dashboard. It is also proposed that the focus of the publication move from solely monitoring progress over time to also identifying hospitals with a high HSMR compared to the Scottish average. This will bring it in line with the current governance process already in place with Healthcare Improvement Scotland (HIS), whereby HIS and ISD routinely review the data to identify patterns in the data and initiate dialogue with Boards, thus improving openness and transparency on how the data is used as recommended by the HSMR Short Life Working Group (Healthcare Improvement Scotland, 2014).
Purpose

1. Since the Scottish Hospital Standardised Mortality Ratio (HSMR) statistics were first released in 2009, extensive dialogue with stakeholders has identified that there may be features of the HSMR model that could be refined and potentially improved upon.

2. This paper is specifically about the HSMR model methodology, and the refinements Information Services Division (ISD) propose to make to improve the risk adjustment of mortality data following the end of the current Scottish Patient Safety Programme (SPSP) aim of reducing mortality by 20% by December 2015. This paper therefore assumes that there will be a desire to continue to publish HSMR data beyond this date, and that the HSMR calculation will continue to include all patients who died within 30-days from hospital admission.

3. Opportunity to implement such improvements must be balanced against the overall policy strategy, which is the continuation of the measure to 2015. As such the current 2009 model will continue to be used until data covering the period up to December 2015 is published at the end of May 2016, after which ISD recommends updating the HSMR model methodology as described in this report.

Background

4. In 2008, the SPSP was established with the overall aim of reducing hospital mortality by 15% by 2012. This was then extended to a 20% reduction by December 2015. Since December 2009, ISD has published quarterly HSMR for all Scottish hospitals participating in the SPSP. HSMRs are provided to enable these acute hospitals to monitor their progress on reducing hospital mortality over time.

5. Since 2009 the Scottish HSMR has been calculated for all acute inpatient and day-case patients admitted to all specialties (medical and surgical). The calculation takes account of patients who died within 30-days from admission, including those that occur after discharge from hospital.

6. The HSMR is calculated as:

\[
\text{HSMR} = \frac{\text{Observed Deaths}}{\text{Predicted Deaths}}
\]

7. To calculate the predicted deaths, a predicted probability of death within 30-days from admission was calculated for each patient. For the 2009 model this was based on the patient’s primary diagnosis; specialty (medical or surgical); age; sex; where the patient was admitted from; the number and severity of prior morbidities in the previous (i) 12 months (ii) 5-years; the number of emergency admissions in the previous 12 months; and whether admitted as an inpatient or day case and type of admission (elective/ non-elective).

8. The baseline year for the 2009 model was October 2006 to December 2007. To calculate the HSMR from the baseline year the predicted probabilities were calculated using data from October 2006 to December 2007. These probabilities were then applied to the data for October 2007 to the latest period. The predicted probabilities were then summed to hospital level in order to produce the predicted number of deaths.
9. The Scottish HSMR analysis is at patient level indexing on the patient’s last stay in the period. This means only one death can be counted for each patient. Therefore, the outcome variable is calculated for each patient using the admission date of the first episode of the last stay and the date of death. The explanatory variables e.g. age, sex, type of admission, inpatient / day case, admitted from and the primary diagnosis are taken from the first episode of the patient’s last stay. If the patient is transferred between hospitals within a stay the outcome is counted against only the first hospital in the stay (see Diagram 1 for an illustration of this).

**Diagram 1: Example patient stay, highlighting first episode from which explanatory variables are taken (2009 Model)**

<table>
<thead>
<tr>
<th>SMR01</th>
<th>Admission Date</th>
<th>Type of Admission</th>
<th>Hospital</th>
<th>Specialty</th>
<th>Main Diagnosis</th>
<th>Discharge Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>01-Oct-12</td>
<td>Emergency</td>
<td>Forth Valley Royal</td>
<td>Orthopaedics</td>
<td>Dislocated Hip</td>
<td>30-Oct-12</td>
</tr>
<tr>
<td></td>
<td>30-Oct-12</td>
<td>Transfer</td>
<td>Forth Valley Royal</td>
<td>Orthopaedics</td>
<td>Blood Transfusion</td>
<td>15-Nov-12</td>
</tr>
<tr>
<td></td>
<td>15-Nov-12</td>
<td>Transfer</td>
<td>Edinburgh Royal Infirmary</td>
<td>General Surgery</td>
<td>Stomach Cancer</td>
<td>19-Nov-06</td>
</tr>
</tbody>
</table>

**Discussion**

10. There is no right way to measure mortality rates as each is a subjective measure which should be interpreted with caution. However, based on feedback from stakeholders, recommendations from the HSMR Short Life Working Group (Healthcare Improvement Scotland, 2014), and research into methods used elsewhere the following refinements to the 2009 HSMR model have been considered within this paper:

- Type of model (decision tree vs. logistic regression)
- Need for calibration of the model every quarter
- Appropriateness of existing diagnostic groups
- Continued use of Prior-Morbidities as a proxy for Co-Morbidities
- Use of Charlson Index to Weight Co-/Prior-morbidities
- Appropriateness of indexing the record at point of admission (particularly in relation to selecting main diagnosis)
- Model Variable Selection

11. This paper discusses the work carried out over 2015-16 to test these refinements and the final proposal for a refined 2016 model and corresponding publication report.

**Type of model (decision tree vs. logistic regression)**

12. The 2009 Model used decision trees (sometimes referred to as classification trees) to find out which explanatory variables best explain hospital mortality and which variables should be used for case-mix adjustment of mortality indicators going forward. The decision tree method was originally used as it was thought that this method would be easier to present to users with a non-statistical background.

13. Another common technique used for this type of analysis is logistic regression (this technique is used in both the HSMR and Summary Hospital-level Mortality Indicator
measures routinely produced and used in England and Wales (Dr Foster Intelligence, 2014) (Health & Social Care Information Centre, n.d.). Logistic regression was also used as part of the validation work to enhance the validity of the current model developed from the decision trees.

14. Regression methods involve fitting a model to data assumed to follow a specified probability distribution, evaluating fit, and estimating parameters that are later used in a prediction equation. Decision tree models take a different approach and successively partition a data set based on the relationships between independent variables and a dependent (outcome) variable. When successful, the resulting tree indicates which independent variables are most strongly related to the dependent variable. It also displays subgroups (terminal nodes) that may have concentrations of cases with desired characteristics. Diagram 2 in Appendix 1 shows a very small part of the decision tree and demonstrates how the data can be partitioned.

15. There have been many studies and papers produced comparing the use of decision tree and logistic regression methods (e.g. (Austin, 2007), (Austin, et al., 2010), (Selker & et.al., 1995)).

16. In theory both approaches should provide similar results. To verify this the two different methods were used to calculate the Scottish HSMR using the 2009 model methodology and then compared. The resulting output was reassuringly very similar. To further assess how the two types of models differentiated between the two outcome groups, alive within 30 days and died within 30 days, Receiver Operating Characteristic (ROC) curves were used. The average area under the curve (AUC) statistic was 0.930 using the decision tree method, whilst it was 0.934 using the logistic regression method. The AUC is a reflection of how good the model is at distinguishing between the two outcome groups (i.e. alive or dead within 30-days of admission). An AUC value of 1.00 represents perfect discrimination between the two outcome groups and a value of 0.5 represents worthless discrimination.

17. As the logistic regression model showed slightly better discrimination than the decision tree method it is proposed that this technique is used in the future as this is easier to adapt, and will also make it easier to apply to other datasets.

**REFINEMENT 1**: Use logistic regression instead of decision trees to find out which explanatory variables should be used for the case mix adjustment of mortality indicators going forward.

**Base period**

18. The 2009 Model is not re-based each quarter nor published with statistical bands around a national average. The baseline year for the 2009 model was October 2006 to September 2007. To calculate the HSMR from the baseline year predicted probabilities were calculated using data from October 2006 to September 2007. These probabilities were then applied to the data for each subsequent quarter.

19. This approach ensured it was possible to continually monitor percentage change from the baseline period, thus measuring progress towards the SPSP aim of reducing mortality by 20% by December 2015.
20. With the continuation of the SPSP measure to December 2015 it was not therefore advisable to re-base the model more frequently as this would prevent us from measuring any reduction in SMRs since the agreed base period. However, as a consequence the 2009 model is predicting current mortality based on historic case-mix and associated mortality rates. Since then there has been a reduction in observed mortality rates, partly due to people living longer and improved outcomes associated with certain conditions. As this is not reflected in the current model the number of predicted deaths will continue to diverge from observed deaths (as illustrated in Figure 1 below).

**Figure 1: Number of Observed and Predicted Deaths as Estimated by 2009 Model; October 2006 to March 2015**

![Graph showing observed and predicted deaths from October 2006 to March 2015.](image)

Source: ISD Scotland (SMR01) linked dataset. Reflects the completeness of SMR01 submissions to ISD for individual hospitals as of 13th July 2015.

21. The approach taken in England for the Summary Hospital Level Mortality Indicator (SHMI) (Health & Social Care Information Centre, n.d.) is to re-base the model every quarter on a rolling basis. This ensures that comparisons that are made against the national average are appropriate and relevant for each point in time. A three year dataset is used to create the risk-adjusted model, with a one year dataset used to score the SHMI and calculate any contextual indicators.

22. This approach ensures that the risk-adjusted measure is based on current case-mix. However, it is only appropriate for time in point comparisons by re-basing the model every quarter it would not be possible to present trend data. As there is still an appetite for an adjusted mortality measure over time in Scotland, a compromise needs to be made regarding the frequency of re-basing.

23. To ensure that comparisons that are made against the national average are appropriate and as relevant for each point in time as possible it is recommended that the model is re-based on a more frequent basis than it is currently, for example every three years using a three year base period instead of one year. Having a static base period for three years will allow us to balance the ability to measure change over time whilst ensuring that predicted mortality is calculated from data that is as up to date as possible. Appendix 2 illustrates the proposed base and reporting periods that will be used following this recommendation.

REFINEMENT 2: Re-base the model every three years. Having a static base period for this set time will allow us to measure change over time, whilst also ensuring that case-mix adjustments remain as relevant as possible.
Primary Diagnosis Grouping

24. When the 2009 HSMR model was produced the clinical group agreed to include all primary diagnoses. Following Dr Fosters HSMR methodology (Aylin, et al., 2009) primary diagnosis was mapped onto 56 clinical classification software (CCS) categories¹ (Agency for Healthcare Research and Quality, 2015). These groupings were found to account for around 83% of diagnoses that preceded a death in Scotland.

25. To allow Scotland to include all diagnoses in the analysis, the clinical group agreed that a smaller number of primary diagnosis groupings should be developed for Scotland to incorporate all diagnoses from the 56 clinical classification groups from Dr Foster and the remaining diagnoses found to precede a death in Scotland. These groupings were to be based on medical intelligence and crude mortality rates. Twenty six groups emerged, made up of a series of system categories (e.g. CVS, Malignancy, Neurological) subdivided according to the level of crude mortality (e.g. Malignancy 1 contains conditions with the lowest level of crude mortality in the malignancy groupings and malignancy 3 contains the conditions with the highest levels). Other than where the mortality rates were low and medical intelligence alone had to be used, there should be no overlap in mortality between groupings within a single system category. Allocation to clinical groupings was particularly difficult when patient numbers were small, and mortality rates became zero. At that point medical intelligence was the only basis on which to allocate a category.

26. One observation of the current model from stakeholders has been that these 26 groupings are not clinically meaningful nor specific enough which can make interpretation more difficult.

27. The Summary Hospital-level Mortality Indicator (SHMI) produced by the Health and Social Care Information Centre (HSCIC) is calculated using 140 different diagnosis groups which are a result of further grouping the 260 mutually exclusive CCS categories produced by Agency for Healthcare Research and Quality (AHRQ).

28. As one of the observations of the 2009 model is the way primary diagnosis has been grouped, it seems sensible to consider expanding these groupings by utilising a pre-defined grouping already used by other similar models i.e. the CCS categories. However, it was thought that 260 groups would be too many for a Scottish model; therefore two different approaches to using the CCS categories were considered.

29. The first approach looked at using the 140 aggregated categories utilised in the SHMI model which include all 260 CCS categories. Lookup Table 1 (Appendix 5) lists the ICD10 codes that have been assigned to each of these groupings. The second approach looked at aggregating these 260 CCS categories for Scotland based on crude mortality using cluster analysis. This approach aggregated the 260 categories into 9 mutually exclusive categories based on crude mortality. Lookup Table 2

¹ There are 260 mutually exclusive CCS categories. These were produced by the Agency for Healthcare Research and Quality (AHRQ) (Agency for Healthcare Research and Quality, 2015) who produced a mapping to assign each ICD-10 code to a Clinical Classification Software (CCS) category for mortality reporting.
Appendix 5 lists the CCS categories, and therefore ICD10 codes, within each of the 9 groupings.

30. Three multivariate logistic regression models were produced using the same explanatory variables and base period currently used by the 2009 model; the only difference between these three models was the primary diagnosis grouping. Model 1 included the 26 groupings as used currently, for model 2 these were replaced by the 140 groupings used by SHMI, and in model 3 these were replaced by the 9 groupings that resulted from the cluster analysis.

31. The AUC statistic for these three models was 0.934 (26 groups), 0.935 (140 groups) and 0.932 (9 groups) respectively. In addition the resulting analysis produced very similar HSMR values at a National level (see Table 2 in Appendix 4). Looking at point in time analysis similar hospitals were also identified as outliers on the funnel plot using both approaches.

32. In conclusion, as the CCS categories are pre-existing and routinely updated to ensure all diagnoses are included, it seems sensible that the Scottish model also makes use of these. Whilst patient numbers within some of these categories are very small, various approaches to grouping them up further have been considered, unfortunately further grouping appears to have a detrimental impact on model fit. As such it is recommended that the 2016 HSMR model utilises the same 140 CCS groupings as HSCIC currently use for the SHMI model.

REFINEMENT 3: Disaggregate current primary diagnosis groupings, utilising the pre-defined CCS groupings as they have been grouped by HSCIC for the SHMI model.

Use of Charlson Index to Weight Co-/Prior-morbidities

33. The Charlson Index was first developed in 1987 (Charlson, et al., 1987) to provide a score based on severity of condition and the number of different conditions the patient has. There are 17 co-morbidity groupings that have been assigned a weight based on severity of condition. An Australian version of the Charlson index (Sundararajan, et al., 2004) was developed in 2004 using the most current classification coding (ICD10). This is used by the 2009 model.

34. Since this index was first developed there have been changes in coding practices, patient case-mix and mortality associated to co-morbid conditions. One example of this is HIV, which previously had the highest weight of all conditions, however there has been a fall in mortality in patients with HIV over a number of years and as such this weight no longer accurately reflects the risk associated with it.

35. Dr Foster Intelligence carried out a piece of work in 2014 (Dr Foster Intelligence, 2014) seeking advice from clinical coders on current English coding practice and assessing, where possible, the consistency of co-morbidity recording among admissions for the same patient. As a result they have expanded the coding definition of some conditions and updated the Charlson Index weightings so that there is greater variation in weights between conditions. Please see Lookup Table 3 (Appendix 5) for the new weightings.
36. The impact of moving to using the revised weightings was tested with two multivariate logistic regression models where prior-morbidities in one and five years were weighted using both approaches. The resulting output was very similar (see Table 3 in Appendix 4); in addition the AUC statistic for both models was the same. However, as the updated index more accurately reflects risk it seems appropriate that the 2016 Scottish model adopts it too.

**REFINEMENT 4: Use updated Charlson Index Weightings as developed by Dr Foster Intelligence, 2014.**

**Co-morbidities vs. Prior Morbidities**

37. In SMR01 data there are 6 diagnosis fields, the main condition and 5 other conditions. Other Conditions are defined as those conditions that co-exist or develop during the episode of healthcare and affect the management of the patient.

38. When the 2009 model was first developed the recording of the other conditions was not always complete across Scotland, ISD were therefore advised to screen back through previous SMR01 records (main diagnosis) to establish a prior-morbidity weighting, according to the Charlson index, as a proxy for co-morbidity.

39. This score was calculated separately looking back 1 and 5 years from the patient’s most recent admission, although did not include the most recent admission as this was used to establish one of the twenty six primary diagnosis groupings.

40. The Data Quality Assurance (DQA) team is responsible for evaluating and ensuring that the ISD Scottish Morbidity Record (SMR) datasets are accurate, consistent and comparable across time and between sources.

41. The DQA team last carried out a quality assurance assessment on SMR01 (General / Acute Inpatient and Day Case) data items specifically in May 2012 (Data Quality Assurance Team (ISD), 2012), covering 2010-2011 data. This report showed that main condition was recorded with an accuracy rate of 88%, whilst recording of other conditions had improved from 72% in 2004-06 to 82% in 2010-11.

42. At the time of writing this report the DQA team were in the final stages of completing the next National SMR01 Assessment, where it is anticipated that accuracy and completeness of other conditions being recorded will have improved further, as indicated at a local level.

43. To further test whether co-morbidities should be included within the 2016 HSMR model, co-morbidities were calculated for each patient and weighted according to the revised Charlson index (See section on Use of Charlson Index to Weight Co-/Prior-morbidities for further information). This variable, along with the two current prior morbidity variables (i.e. prior-morbidities in last 1 year and prior-morbidities in last 5 years, also weighted according to the updated Charlson index), were then included in a multivariate logistic regression model. All three variables had a significant effect on the outcome (whether the patient was alive or dead within 30 days) in the multivariate model (p<0.05) (please see section on Model Variable Selection for further
information). As such it is recommended that a co-morbidities variable is added to the refined model, alongside prior morbidities in the last 1 and 5 years.

REFINEMENT 5: Add co-morbidities to the refined HSMR model, taken from the first episode of the patient’s last continuous inpatient stay (CIS) in the reporting period.

Admission vs. Discharge Episode

44. SMR01 data are episode based. A continuous inpatient stay (CIS) is defined as all SMR01 records referring to the same continuous spell of inpatient treatment (whether or not this involves transfer between hospitals or even between NHS Boards). Intermediate episodes are initiated by a change in care, for instance a transfer from one department to another. There may be many or no intermediate episodes, and the admission episode and the discharge episode may be the same episode, for instance if a patient was admitted to and discharged from the emergency department with no need for further inpatient care.

45. CISs are built up by examining the intervals between successive linked records for a given patient. Thus for each interval a decision is made as to whether the records constitute part of a continuous stay according to defined rules. Apart from the length of the interval between two records, decisions hinge on whether the type of discharge of the first record and type of admission on the second record is a transfer.

46. In the 2009 HSMR model the outcome variable is calculated for each patient using the admission date of the first episode of the last stay and the date of death. The explanatory variables are also taken from the first episode of the patient’s last stay. If the patient is seen in more than one hospital within a stay the outcome is counted against only the first hospital in the stay as shown in Diagram 1 earlier.

47. Over the years there has been some debate over whether or not the explanatory variables should be taken from the first or last episode of the patient stay, in particular primary diagnosis. This was tested by producing two multivariate logistic regression models, one taking all the explanatory variables as used in the 2009 model from the first episode and one taking all the explanatory variables from the last episode. The difference between the two approaches was negligible. This is illustrated in Table 4 (Appendix 4) which compares Scottish SMRs by quarter using both approaches. In addition, funnel plots were used to compare hospitals against the national average. Table 5 (Appendix 4) shows which hospitals if any were above 2 and 3 standard deviations from the Scottish average for the last four quarters available at the time of this analysis. This shows that indexing on first or last episode has very little impact at hospital level, with the same hospitals identified as outliers using both approaches in all but one quarter. As such it is proposed that the 2016 model continues to take the explanatory variables from the first episode which is a much cleaner analysis from a statistical point of view.
Model Variable Selection
48. The 2009 model used the following ten explanatory variables for case-mix adjustment:

- Age
- Sex
- Type of admission (Elective, Emergency/ Transfer)
- Inpatient/ Day case
- Where a patient was admitted from (Institution, Private Residence, Temporary, Transfer from other NHS provider, Transfer from same provider and Other)
- Previous emergency admissions
- Primary diagnosis
- Prior-morbidities in the previous 1 year
- Prior-morbidities in the previous 5 years
- Specialty (surgical/ non-surgical)

49. As noted earlier, the predicted probabilities for the 2009 model were calculated using data from October 2006 to December 2007. Refinement 1 proposes that this base period is updated quarterly on a rolling basis; as such consideration needs to be given to whether these variables continue to best explain hospital mortality.

50. In the past it has been suggested that the following additional five variables may also be an indicator of 30-day mortality:

- Co-morbidities
- Scottish Index of Multiple Deprivation
- Type of hospital (e.g. Teaching, Large General, Small General, Other)
- Season (e.g. Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec)
- Day of week

51. Using a three year dataset logistic regression analyses were performed in order to examine the relationship between each of these 15 explanatory variables and the outcome (whether the patient was alive or dead within 30 days). Univariate analyses were carried out to determine which of the 15 variables should be used for the case mix adjustment of mortality indicators (See Table 6 in Appendix 4).

52. Each of the variables from the univariate analyses were initially included in a multivariate logistic regression model. Following this further models were tested by removing one explanatory variable at a time. Using Goodness of Fit Tests\(^2\) and Receiver Operating Curves\(^3\) to assess calibration and discrimination, the following variables were excluded from the final model as they either did not have a significant effect on the outcome or did not improve the overall fit: season, day of the week and hospital type.

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\(^2\) The Log Likelihood Ratio Test was used to compare each reduced model to the full model. This produces a chi-square distribution. If the statistical significance of the chi-square distribution is significant at a 0.05 level then the difference in prediction between the reduced model and the full model is statistically significant, so the full model is preferred.

\(^3\) To assess whether this model differentiates between the two outcome groups, alive within 30 days and died within 30 days, Receiver Operating Characteristic (ROC) curves were used. An area under the curve (AUC) value of 1.00 represents perfect discrimination between the two outcome groups and a value of 0.5 represents worthless discrimination.
Interactions

53. Two way interactions between the 12 remaining variables were also tested. The presence of a significant interaction indicates that the effect of one predictor variable on the outcome variable is different at different values of the other predictor variable.

54. Whilst there were a number of significant interactions, when these interaction terms were added to the multivariate model they no longer had a significant effect on the outcome variable nor did they improve model fit i.e. adding these interaction terms did not help explain any more variance in the model. The main effects model without these interactions was therefore chosen.

55. Table 7 (Appendix 4) shows the results from the final multivariate analysis, including the additional variables co-morbidities and hospital type. This final model has an AUC value of 0.937.

REFINEMENT 6: Use the following explanatory variables for case-mix adjustment:

- Age (continuous)
- Sex (categorical)
- Admission Type (Elective/ Non-Elective) (categorical)
- Inpatients/ Daycase (categorical)
- Where a patient was admitted from (Institution, Private Residence, Temporary, Transfer from other NHS provider, Transfer from same provider and Other) (categorical)
- Previous emergency admissions (categorical)
- Primary diagnosis (categorical)
- Prior-morbidities in the previous 1 year (continuous)
- Prior-morbidities in the previous 5 years (continuous)
- Co-morbidities (continuous)
- Specialty (surgical/ non-surgical) (categorical)
- Scottish Index of Multiple Deprivation (categorical)

Results

56. HSMRs were calculated for each hospital participating in the SPSP using the proposed 2016 model methodology as summarised in Table 1 (Appendix 3).

57. Table 8 in Appendix 4 shows the anonymised results from this model for the period January 2011 (start of new base period) to September 2015 (latest available at time of finalising this report).

58. Please note that the results from this model should not be compared to the 2009 model. Whilst crude mortality rates will be very similar using both approaches, the period from which predicted probabilities are calculated differs.

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4 Crude mortality will not be identical using both the 2009 and 2016 models. This is because patients without a predicted probability of death calculated from the 2009 model are excluded from the analysis; this has also increased over time. With the 2016 model a predicted probability of death is calculated for every patient. As a direct result this means that there are also slightly larger numbers of observed deaths calculated with the 2016 model.
59. This more recent base period will account for patients living longer, and mortality associated with certain conditions e.g. HIV improving. As a result the 2016 model will not predict as high a probability of death to certain patients as the 2009 model would have based on case-mix and outcomes in 2006/07. Therefore the SMRs calculated under the 2009 and 2016 model methodologies should only ever be considered in the context of the appropriate base periods used for each and should not be compared to each other.

60. Figures 2 to 4 show graphical results from the 2016 model. Figure 2 provides time in point comparisons using a funnel plot for the latest quarter (Jul-Sep 15), and Figure 3 shows HSMR at Scotland level for the full 2016 model reporting period up to September 2015 (latest available), whilst Figure 4 shows trends in crude mortality.

61. The funnel plot is a Statistical Process Control (SPC) chart for cross-sectional data at a particular point in time. It allows comparisons to be made between each hospital and the average for Scotland for a particular period. The rate of the process (i.e. HSMR) is plotted on the vertical axis and the denominator (i.e. predicted deaths) is plotted on the horizontal axis.

62. There are three key lines in the funnel plots presented here. The first, depicted in dark blue, is the average for Scotland. Plotted on either side of the average are two sets of curved lines called control limits (red). The red control limits are plotted at 3 standard deviations (SDs) from the average. Orange warning limits have also been plotted on the charts presented here, at 2 standard deviations (SDs) from the average. Although usually, only control limits are calculated as the warning limits do not apply to cross-sectional data.

63. The reason the red and orange lines are curved – and the limits are wider at the left hand side of the graph (thus the name funnel plot) – is because the data points plotted at this side of the graph (typically representing smaller hospitals) are made up of fewer observations and are therefore subject to greater variability. This means that smaller hospitals will appear towards the left hand side of the graph and larger hospitals towards the right.

64. Figure 2 shows the funnel plot for the latest quarter, which shows that there are no hospitals over the upper control limits at 3SDs from the Scottish average for this quarter; however there are two hospitals over the upper warning limits at 2SDs from the Scottish average. Figure 3 shows the HSMR trend chart for Scotland which exhibits clear seasonal variation although a reasonably flat trend. This is further reflected in the crude mortality trend chart for the same time period shown in Figure 4.
Figure 2: 2016 Model - Hospital Standardised Mortality Ratio Funnel Plot (Jul-Sep 15)

![Standardised Mortality Ratio Funnel Plot](image)

Figure 3: 2016 Model – Hospital Standardised Mortality Ratio; Scotland: January 2011 to September 2015

![Standardised Mortality Ratio Graph](image)
Figure 4: 2016 Model – Crude Mortality within 30-days of admission; Scotland: January 2011 to September 2015

Summary

65. In this paper a number of refinements to the current model have been considered. The largest one of which is updating the period on which the model is based and therefore used to calculate the predicted probabilities.

66. In summary the following refinements are proposed to the model itself:

- Move to using a logistic regression model instead of a decision tree model to calculate risk-adjusted mortality.
- Re-base model on a more frequent basis. This will ensure that the predicted probabilities used within the HSMR calculation is based on more up to date data.
- Use updated Charlson Index weightings as produced by Dr Foster (Dr Foster Intelligence, 2014).
- Update the primary diagnosis groupings using the 140 groupings based on CCS categories utilised by SHMI (Health & Social Care Information Centre, n.d.).
- Add co-morbidities and Scottish Index of Multiple Deprivation to the explanatory variables.

Future Publications

67. The current 2009 model will continue to be used until data covering the period up to December 2015 is published at the end of May 2016, after which Information Services Division (ISD) recommends updating the HSMR model methodology as described in this report.

68. Following this, ISD propose continuation of a written quarterly publication alongside an interactive dashboard (screenshots of a prototype dashboard are provided in Appendix 6). The focus of the publication will move from solely monitoring progress over time to also identifying hospitals with a high HSMR compared to the Scottish average at each quarter. This will be presented using Funnel Plots, which will allow comparisons to be made between each hospital and the average for Scotland for a
point in time. Funnel plots are a simple way of presenting data that can help guide quality improvement activities, by flagging up areas where there appears to be marked variation and where further local investigation might be beneficial. This will bring it in line with the current governance process already in place with Healthcare Improvement Scotland (HIS), whereby HIS and ISD routinely review the data to identify patterns in the data and initiate dialogue with Boards, thus allowing us to be open and transparent on how the data is used.
References


Appendices

Appendix 1 – Decision Tree

584,922 patients
4.6% mortality within 30 days

Surgical specialties
328,834 (1.5%)

Prim diag = Gastro2 or CVS2
2485 (10.4%)

Age <=44
604 (1.0%)

Non-surgical specialties
256,088 (8.6%)

Prim diag = Malig3
4675 (53.1%)

Non-elective admission
3251 (64.7%)

Previous emerg adms >0
1837 (69.2%)

Sex = Male
992 (71.3%)

Predicted probability of death within 30-days of admission
= 0.01

Predicted probability of death within 30-days of admission
= 0.71
## Appendix 2 - Base & Reporting Periods

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Base Period</th>
<th>Reporting Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-Mar 2016</td>
<td>Jan 11 to Dec 13</td>
<td>Jan 11 to Mar 16</td>
</tr>
<tr>
<td>Apr-Jun 2016</td>
<td>Jan 11 to Dec 13</td>
<td>Jan 11 to Jun 16</td>
</tr>
<tr>
<td>Jul-Sep 2016</td>
<td>Jan 11 to Dec 13</td>
<td>Jan 11 to Sep 16</td>
</tr>
<tr>
<td>Oct-Dec 2016</td>
<td>Jan 11 to Dec 13</td>
<td>Jan 11 to Dec 16</td>
</tr>
<tr>
<td>Jan-Mar 2017</td>
<td>Jan 11 to Dec 13</td>
<td>Jan 11 to Mar 17</td>
</tr>
<tr>
<td>Apr-Jun 2017</td>
<td>Jan 11 to Dec 13</td>
<td>Jan 11 to Jun 17</td>
</tr>
<tr>
<td>Jul-Sep 2017</td>
<td>Jan 11 to Dec 13</td>
<td>Jan 11 to Sep 17</td>
</tr>
<tr>
<td>Oct-Dec 2017</td>
<td>Jan 11 to Dec 13</td>
<td>Jan 11 to Dec 17</td>
</tr>
<tr>
<td>Jan-Mar 2018</td>
<td>Jan 11 to Dec 13</td>
<td>Jan 11 to Mar 18</td>
</tr>
<tr>
<td>Apr-Jun 2018</td>
<td>Jan 11 to Dec 13</td>
<td>Jan 11 to Jun 18</td>
</tr>
<tr>
<td>Jul-Sep 2018</td>
<td>Jan 11 to Dec 13</td>
<td>Jan 11 to Sep 18</td>
</tr>
<tr>
<td>Oct-Dec 2018</td>
<td>Jan 11 to Dec 13</td>
<td>Jan 11 to Dec 18</td>
</tr>
</tbody>
</table>

### RE-BASE

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Base Period</th>
<th>Reporting Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-Mar 2019</td>
<td>Jan 14 to Dec 16</td>
<td>Jan 14 to Mar 19</td>
</tr>
<tr>
<td>Apr-Jun 2019</td>
<td>Jan 14 to Dec 16</td>
<td>Jan 14 to Jun 19</td>
</tr>
<tr>
<td>Jul-Sep 2019</td>
<td>Jan 14 to Dec 16</td>
<td>Jan 14 to Sep 19</td>
</tr>
<tr>
<td>Oct-Dec 2019</td>
<td>Jan 14 to Dec 16</td>
<td>Jan 14 to Dec 19</td>
</tr>
</tbody>
</table>
### Appendix 3 - Summary of Refinements

**Table 1: Summary of Refinements to the Scottish HSMR Model Methodology**

<table>
<thead>
<tr>
<th></th>
<th>2009 Model</th>
<th>2016 Model</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Model</strong></td>
<td>Decision Tree</td>
<td>Logistic Regression</td>
<td>Easier to update &amp; refine in future.</td>
</tr>
<tr>
<td><strong>Base Period</strong></td>
<td>October 2006 to December 2007</td>
<td>Three year dataset update once every three years.</td>
<td>Ensures predicted probabilities are calculated using more up to date data whilst also allowing changes over time to be measured using adjusted data.</td>
</tr>
<tr>
<td><strong>Explanatory Variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Age</td>
<td>• Age</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Gender</td>
<td>• Gender</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Type of Admission (Elective/ Non-Elective)</td>
<td>• Type of Admission (Elective/ Non-Elective)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Inpatient/ Day Case</td>
<td>• Inpatient/ Day Case</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Where a patient was admitted from (Institution, Private residence, Temporary, Transfer from other NHS provider, Transfer from same provider and Other)</td>
<td>• Where a patient was admitted from (Institution, Private residence, Temporary, Transfer from other NHS provider, Transfer from same provider and Other)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Number of Emergency Admissions in previous 1 year</td>
<td>• Number of Emergency Admissions in previous 1 year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Primary Diagnosis</td>
<td>• Primary Diagnosis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Prior-morbidities in the previous 1 year</td>
<td>• Prior-morbidities in the previous 1 year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Prior-morbidities in the previous 5 years</td>
<td>• Prior-morbidities in the previous 5 years</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Specialty (Surgical/ Non-Surgical)</td>
<td>• Specialty (Surgical/ Non-Surgical)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Primary Diagnosis Groupings</strong></td>
<td>26 based on medical intelligence and crude mortality rates</td>
<td>140 based on CCS groupings</td>
<td>More clinically meaningful, and routinely utilised by other organisations routinely producing similar statistics.</td>
</tr>
<tr>
<td><strong>Charlson Index</strong></td>
<td>2004 Australian Version of the Charlson Index (Sundararajan, et al., 2004)</td>
<td>Revised weightings based on work by Dr Foster Intelligence (Dr Foster Intelligence, 2014)</td>
<td>More accurately reflects risk.</td>
</tr>
</tbody>
</table>
Appendix 4 – Tables
Available in the Excel workbook below:

HSMR-Model-Review-Data-Tables

Appendix 5 – Lookups
Available in the Excel workbook below:

HSMR-Model-Review-Lookup-Tables
Appendix 6 – Sample screenshots of a prototype HSMR Dashboard

Hospital Standardised Mortality Ratios
Publication Date: 17th November 2015

Health Board Code: Greater Glasgow & Clyde
Quarter: 3

<table>
<thead>
<tr>
<th>Health Board Code</th>
<th>Hospital Code</th>
<th>Number of Deaths</th>
<th>Predicted Number of Deaths</th>
<th>HSMR</th>
<th>Number of Patients</th>
<th>Crude Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glasgow Royal Infirmary</td>
<td>426</td>
<td>401</td>
<td>1.06</td>
<td>17,019</td>
<td>2.42</td>
<td></td>
</tr>
<tr>
<td>Inverclyde Royal Hospital</td>
<td>183</td>
<td>227</td>
<td>1.28</td>
<td>8,818</td>
<td>3.38</td>
<td></td>
</tr>
<tr>
<td>Queen Elizabeth University Hospital</td>
<td>871</td>
<td>787</td>
<td>1.03</td>
<td>30,247</td>
<td>2.74</td>
<td></td>
</tr>
<tr>
<td>Royal Alexandra Hospital/Val of Lesse</td>
<td>319</td>
<td>329</td>
<td>1.05</td>
<td>11,789</td>
<td>3.39</td>
<td></td>
</tr>
</tbody>
</table>

Source: ISD Scotland (ISWPD) (IHR) database. The tabulation includes 187 independent submissions to ISD for individual hospitals as of 13th October 2015. p - provisional.