### Document Control

<table>
<thead>
<tr>
<th>Version</th>
<th>Date Issued</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>July 2016</td>
<td>Quality Indicators Team</td>
</tr>
</tbody>
</table>

### Comments to
NSS.isdQualityIndicators@nhs.net

### Document History

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Comment</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>23/02/2016</td>
<td>Version 1</td>
<td>Robyn Munro</td>
</tr>
</tbody>
</table>
CONTENTS

1. OVERVIEW .............................................................................................................4

2. INTRODUCTION ......................................................................................................5
   2.1 Reporting Frequency .........................................................................................5
   2.2 Description ..........................................................................................................5

3. METHODS ...................................................................................................................5
   3.1 Source Data .........................................................................................................5
   3.2 Level of Analysis (Patient-Based) ......................................................................5
   3.3 Outcome Variable – Observed Deaths ...............................................................6
   3.4 Explanatory Variable - Predicted Deaths .........................................................6
      3.4.1 Primary Diagnosis ......................................................................................6
   3.5 Prior & Co-Morbidities ......................................................................................7
      3.5.1 Prior Morbidity ..........................................................................................8
      3.5.2 Co-Morbidity .............................................................................................8
      3.5.3 Charlson Index ...........................................................................................8
   3.6 Palliative Care .....................................................................................................9
   3.7 Base Period .........................................................................................................9
   3.8 Logistic Regression ............................................................................................9
      3.8.1 Validation ....................................................................................................10
      3.8.2 Discrimination ...........................................................................................10
      3.8.3 Calibration ..................................................................................................10

4. REFERENCES ...........................................................................................................12

5. APPENDICES ...........................................................................................................13
   5.1 Appendix 1 – Mappings .....................................................................................13
   5.2 Appendix 2 – Summary of Refinements ..............................................................14
1. OVERVIEW

Most deaths that occur in hospital are inevitable because of the patient’s condition on admission. Some deaths can be prevented, however, by improving care and treatment or by avoiding harm.

Hospital Standardised Mortality Ratios (HSMR) adjust mortality data to take account of some of the factors known to affect the underlying risk of death. They include all acute inpatient and day-case patients admitted to all medical and surgical specialties (excluding obstetrics and psychiatry).

The HSMR calculation includes patients who died within 30-days from hospital admission. This means that the HSMR includes deaths that occurred in the community (deaths that did not happen in hospital) as well as those occurring in-hospital.

Since December 2009, the Information Services Division (ISD) of NHS National Services Scotland (NSS) has published quarterly HSMRs for all Scottish hospitals participating in the Scottish Patient Safety Programme (SPSP).

In 2013, an HSMR Short Life Working Group was commissioned and led by Healthcare Improvement Scotland (HIS), with involvement of ISD, Scottish Government and a number of NHS Boards. A series of recommendations from this group on the HSMR in Scotland were published in 2014. One of these recommendations was to critically review and refine the model used to produce the HSMR. This was to coincide with the end of the SPSP aim of reducing mortality by 20% by the end of December 2015 (published in May 2016).

ISD carried out a full review of the methodology used to produce the HSMR. An HSMR Review paper was produced which included recommendations for refining the model following the May 2016 release. The main changes to the model methodology from August 2016 onwards are summarised in Appendix 2.

This methodology and specification document outlines the refined HSMR model specification, used to produce the quarterly HSMR from August 2016 onwards.
2. **INTRODUCTION**

2.1 **Reporting Frequency**

The Scottish HSMR is updated and reported on quarterly. From August 2016 the model will be re-based every three years.

2.2 **Description**

The HSMR is calculated as:

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

The observed number of deaths is the total number of patients who died within 30-days of admission to hospital.

The predicted number of deaths is calculated from a case-mix adjusted model 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 severity of co-morbidities; the number of emergency admissions in the previous 12 months; whether admitted as an inpatient or day case; type of admission (elective/ non-elective); and deprivation.

From August 2016 a three year dataset has been used to create the model. The three year period used for the dataset will be updated every three years, however until then the base period will be January 2011 to December 2013.

3. **METHODS**

3.1 **Source Data**

The HSMR measure is derived from hospital non-obstetric and non-psychiatric inpatient and day case activity (SMR01) linked together at patient level. The hospital patient-profiles are further linked to the National Records of Scotland (NRS) death records.

The linkage of SMR01/NRS data means all mortality, including deaths occurring in the community following hospital discharge, and not just in-hospital mortality can be looked at.

3.2 **Level of Analysis (Patient-Based)**

SMR01 data are episode based. A patient can have more that one episode within a continuous inpatient stay, where there is a change in consultant or facility for example. 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). 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. A patient could have more than one stay within the time period,
however as the stays for each person are linked, any analysis can be at either patient or stay level. For the Scottish HSMR, analysis is at patient level.

If the analysis were at stay level (rather than patient level) this would mean that patients and deaths could be counted more than once. From a statistical view stays should not be considered independent and therefore only one stay should be included. From a clinical view the most recent stay is deemed to be the most appropriate selection. Therefore the analysis is at patient level indexing on the patient’s last stay in the period. This means no more than one death will be counted for each patient. Therefore, the outcome variable is calculated for each patient using two dates: the admission date of the first episode of the last stay and the date of death. For the explanatory variable the age, sex, deprivation, type of admission, inpatient / day case, admitted from, primary diagnosis and co-morbidities are 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.

3.3 Outcome Variable – Observed Deaths
The outcome is whether the patient was alive or dead within 30 days of admission.

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. 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.

Patients with admissions in different quarters will be counted in each quarter. If a patient was admitted in one quarter but died in the subsequent quarter, any admissions in this latter quarter are excluded. This ensures that the analysis is patient-based, within quarter, and that deaths are counted only once.

3.4 Explanatory Variable - Predicted Deaths
To calculate the predicted deaths, a predicted probability of death within 30 days from admission needs to be calculated for each patient based on the patient’s:

- 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)
- Number of emergency admissions in previous 1 year
- Primary diagnosis
- Prior-morbidities in the previous 1 and 5 years
- Co-morbidities
- Specialty (Surgical / non-surgical)
- Scottish Index of Multiple Deprivation (1 = most deprived, 5 = least deprived)

This is taken from the first episode of the patient’s last stay.

3.4.1 Primary Diagnosis
When the previous Scottish HSMR model was produced in 2009 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) categories (Agency for Healthcare Research and Quality, 2015). These groupings were found to account for around 83% of diagnoses that preceded a death in Scotland.
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.

One observation of the previous Scottish HSMR model from stakeholders was that these 26 groupings were neither clinically meaningful nor specific enough making interpretation more difficult. It therefore seemed sensible to consider expanding these groupings by utilising a pre-defined grouping already used by other similar models; namely the Clinical Classification Software (CCS) categories.

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. However, it was felt that a smaller number of primary diagnosis groupings should be used for Scotland, incorporating all diagnoses from the 260 CCS groups.

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.

As the CCS categories are pre-existing, routinely updated to ensure all diagnoses are included, and improve model fit, it seemed sensible that the Scottish model also made use of these. Reference Tables lists the ICD10 codes that have been assigned to each of these groupings now used in the Scottish HSMR model.

3.5 Prior & Co-Morbidities
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.

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.

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

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.

As such it was felt that other conditions are now complete enough to be used to calculate co-morbidity weightings alongside the prior-morbidity weightings which continue to remain in the model as they continue to have a significant effect on the outcome (whether the patient was alive or dead within 30 days).

3.5.1 Prior Morbidity
To establish a prior-morbidity weighting, according to the Charlson index, scores are calculated separately looking back 1 and 5 years from the patient’s most recent admission. This score does not include the most recent admission, which is used to calculate the co-morbidity score and primary diagnosis grouping.

For example, if a patient had a previous main condition of acute myocardial infarction (weight=1) and a further episode coded with diabetes complications as the main condition (weight=2), their prior-morbidity score would be 3. This would hold true if both conditions occurred within 1 or 5 years of the index admission. Each of the 17 conditions should only be counted once within the screening period (1 or 5 years).

3.5.2 Co-Morbidity
To establish a co-morbidity weighting, according to the Charlson index, scores are calculated from the 5 other conditions recorded under a patient’s most recent admission. The main condition is used to calculate the primary diagnosis grouping.

3.5.3 Charlson Index
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 was used by the previous HSMR model, built in 2009.

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.

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 Reference Tables for the new weightings which are now used in the Scottish HSMR model.

3.6 Palliative Care
A palliative care adjustment is not made in the national model. The specialty / significant facility of palliative medicine recorded on SMR01 would not capture all palliative cases. There is no information on the cancer registry, for palliative cancer and although ISD has started collecting hospice data they are very incomplete.

3.7 Base Period
A three year dataset is used to create the risk-adjusted model, this three year base period is updated every three years to ensure the predicted probabilities associated with patient case-mix is as relevant as possible whilst still maintaining our ability to present trends.

The current base period is January 2011 to December 2013.

3.8 Logistic Regression
Using a three year dataset, as defined above, logistic regression analyses are performed in order to examine the relationship between each of the explanatory variables and the outcome (whether the patient was alive or dead within 30 days).

The explanatory variables used in the case-mix adjustment are:

Outcome:
- Mortality (0=Alive within 30 days, 1=Died within 30 days)

Independent variables:
- Age (Continuous)
- Sex (Binary variable: 1=Male, 2=Female)
- Scottish Index of Multiple Deprivation (Ordered categorical variable: 1 to 5)
- Type of admission (Binary variable: 1=Elective, 2=Emergency / Transfer)
- Inpatient / Day case (Binary variable)
- Admitted from (Nominal categorical variable: 1=Institution, 2=Private residence, 3=Temporary, 4=Transfer from other NHS provider, 5=Transfer from same provider and 6=Other)
- Previous emergency admissions (Continuous)
- Primary diagnosis (Nominal categorical variable)
- Prior-morbidities in last 1 and 5 years (Continuous)
- Co-Morbidities (Continuous)
- Specialty (Nominal categorical variable)

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.
The predicted probability of death within 30-days is calculated for every case-mix combination as:

\[
\text{Predicted Probability} = \frac{e^{\text{logodds}}}{1 + e^{\text{logodds}}}
\]

where,

\[
\text{logodds} = \beta_0 + \sum_{i=1}^{j} \beta_i x_i
\]

- \( \beta_0 \) = coefficient on the constant term
- \( \beta_1, \ldots, \beta_j \) = coefficient(s) on independent variables
- \( x_1, \ldots, x_j \) = independent variables

The HSMR is calculated using a one year dataset, as defined above. For each hospital \( h \) the HSMR is:

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

where,

- \( \text{Observed Deaths}_h = \sum_{j} \text{Numerator}_h \) = the sum of patients who have died within 30-days of admission for hospital \( h \) over all case-mixes \( j \).
- \( \text{Predicted Deaths}_h = \sum_{j} \text{Predicted Probabilities}_h \) = the sum of predicted probabilities for hospital \( h \) over all case-mixes \( j \).

### 3.8.1 Validation

A three year dataset is used to create the risk-adjusted model.

For any prognostic model there are two aspects of performance to assess, the discrimination and the calibration.

#### 3.8.2 Discrimination

To assess whether the model differentiates between the two outcome groups, alive within 30 days and died within 30 days, Receiver Operating Characteristic (ROC) curves were used. The area under the curve (AUC) statistic was 0.937. (An AUC value of 1.00 represents a perfect discrimination between the two outcome groups and a value of 0.5 represents worthless discrimination.)

#### 3.8.3 Calibration

Calibration evaluates how well the predicted probabilities of death estimated by a model compare with the actual number of patients that died; this can be tested using goodness-of-fit statistics.

Goodness-of-fit statistics examine the difference between the observed and predicted frequencies for groups of patients. The statistic can be used to determine if the model provides a good fit for the data.

The Log Likelihood Ratio Test was used to test whether the observed difference in model fit of a null model (with no case-mix adjustment) to a full model (adjusting for explanatory variables) was statistically significant. The Log Likelihood Ratio Test does this by
comparing the log likelihoods of the two models, and produces a chi-square distribution. The statistical significance of the chi-square distribution was significant, meaning that the full model was considered to fit the data significantly better than the null model.
4. REFERENCES


5. APPENDICES

5.1 Appendix 1 – Mappings

A number of mappings have been applied retrospectively to certain fields within the source records (SMR01). This has been carried out in order to form broader categories, more appropriate for stable statistical modelling and analyses.

Descriptions of how these mappings have been applied are presented in the Reference Tables.

**Diagnosis Groupings** sheet shows how each of the individual ICD-10 clinical codes has been assigned to one of the 140 aggregated CCS primary diagnosis groupings used for the main diagnosis adjustment in the Scottish HSMR.

**Charlson Index** sheet lists the ICD-10 codes that have been assigned to each of the seventeen Charlson Index categories used for the prior-morbidity adjustment in the Scottish HSMR.

Further information on the International Classification of Diseases including access to an online reference manual (ICD-10) is available on the World Health Organisation (WHO) website.

**Surgical Specialties** sheet describes how each of the individual specialty codes has been assigned to a surgical / non-surgical variable.

**Admission Type** sheet describes how each of the type of admission codes has been assigned to an elective / non-elective variable.
### 5.2 Appendix 2 – Summary of Refinements

Refinements made to the model methodology; effective from August 2016

<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 updated 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>Age; Gender; Type of Admission (Elective/ Non-Elective); patient/ Day Case; Where a patient was admitted from (Institution, Private residence; Temporary; Transfer from other NHS provider; Transfer from same provider and Other); Number of Emergency Admissions in previous 1 year; Primary Diagnosis; Prior-morbidities in the previous 1 and 5 years; Specialty (Surgical/ Non-Surgical)</td>
<td>Age; Gender; Type of Admission (Elective/ Non-Elective); patient/ Day Case; Where a patient was admitted from (Institution, Private residence; Temporary; Transfer from other NHS provider; Transfer from same provider and Other); Number of Emergency Admissions in previous 1 year; Primary Diagnosis; Prior-morbidities in the previous 1 and 5 years; Co-morbidities; Specialty (Surgical/ Non-Surgical); Deprivation</td>
<td>Reflects variables which have the most significant effect on the outcome based on most recent data.</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>