HSMR - technical specifications - 2022

Technical specification document

Publication date: August 2019 onwards
Translations and other formats are available on request at:

@ phs.otherformats@phs.scot

0131 314 5300

Public Health Scotland is Scotland's national agency for improving and protecting the health and wellbeing of Scotland's people.

© Public Health Scotland

This publication is licensed for re-use under the Open Government Licence v3.0.

For more information, visit
www.publichealthscotland.scot/ogl

www.publichealthscotland.scot
## Version history

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Summary of changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>24/04/2019</td>
<td>Initial version</td>
</tr>
<tr>
<td>1.1</td>
<td>27/09/2022</td>
<td>Text improvements and rebranding</td>
</tr>
</tbody>
</table>
# Contents

Overview 4  
Introduction 6
  Reporting Frequency 6  
  Description 6  
Methods 7
  Source data 7  
  Level of analysis (Patient-based) 7  
  Outcome variable – Observed deaths 8  
  Explanatory variable - Predicted Deaths 8
    Primary diagnosis 9  
  Prior & comorbidities 10
    Prior morbidity 11
    Comorbidity 11
    Charlson Index 12  
Palliative care 12  
Base period 13  
Reporting period 13  
Logistic regression 13
  Validation 16
  Discrimination 16
  Calibration 16
References 17  
Appendix 1 – Mappings 19
Appendix 2 – Funnel Plot 20
  What is a funnel plot? 20  
  Overdispersion 21  
  How to interpret a funnel plot 21
Appendix 3 - Adjusting funnel plot control limits for overdispersion

Overdispersion

Winsorising

Calculating overdispersion factor (\(\varphi\))

Calculating lower and upper limits for funnel plot
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, Public Health Scotland (previously Information Services Division) has published quarterly HSMRs for all Scottish hospitals participating in the Scottish Patient Safety Programme (SPSP).

Since the HSMR statistics were first released in 2009, PHS have periodically reviewed the model methodology to ensure that it continues to be robust and that comparisons which are made against the national average continue to be appropriate and relevant for each point in time.

Any improvements needed to be balanced against the overall policy strategy and purpose of the HSMR which, since 2016, was to monitor progress towards the Scottish Patient Safety Programme aim of reducing mortality by a further 10% by end December 2018.

The end of this phase of the SPSP provided the opportunity to review the model methodology for a second time (the last significant review took place in 2015/16) and subsequently update/refine it.

The main changes are:
• Moving to a dynamic three-year base period, advanced by three months with each reporting period, ensuring the Scottish HSMR is always representative of current outcomes and reflective of changing case-mix and provision of services.

• Move to a twelve-month reporting period – rather than three months – when drawing comparisons against the national average, smoothing out seasonal variation and reducing variation for smaller hospitals.

• Use less aggregated specialty groupings to improve performance of the model and allow more in-depth analysis.

This methodology and specification document outlines the refined HSMR model specification, used to produce the quarterly HSMR from August 2019 onwards.
Introduction

Reporting frequency

The Scottish HSMR is updated and reported on quarterly.

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; 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 comorbidities; 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 2019 a dynamic three-year dataset has been used to create the model. The three-year period used for the dataset is advanced by three months with each reporting period.
Methods

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.

Level of analysis (Patient-based)

SMR01 data are episode based. A patient can have more than 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 reporting period. This means no more than one death will be counted for each patient.

**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.

**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
- Comorbidities
• Specialty

• Scottish Index of Multiple Deprivation (1 = most deprived, 5 = least deprived)

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

Primary diagnosis

When the Scottish HSMR model was first 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.

When the Scottish HSMR model methodology was reviewed in 2015, one observation 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) 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 list the ICD10 codes that have been assigned to each of these groupings used in the Scottish HSMR model since 2015.

Prior & comorbidities

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, PHS (ISD at the time) 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 comorbidity.

However, the Data Quality Assurance (DQA) team within PHS (who are responsible for evaluating and ensuring that the PHS 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 covering 2014-2015 data. This report showed that main condition was recorded with an accuracy rate of 89%, whilst recording of other conditions was not assessed in this report, previous reports showed that this had improved from 72% in 2004-06 to 82% in 2010-11.

At the time of writing this report the DQA team were beginning their 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.

We therefore consider that other conditions are complete enough to be used to calculate comorbidity weightings alongside the prior-morbidity weightings, which are also included within the model as they continue to have a significant effect on the outcome (whether the patient was alive or dead within 30 days).

**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 comorbidity score and primary diagnosis grouping.

For example, if a patient had a previous main condition of acute myocardial infarction (weight=5) and a further episode coded with diabetes as the main condition (weight=3), their prior-morbidity score would be 8. 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).

**Comorbidity**

To establish a comorbidity 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.
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 comorbidity 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 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 comorbid 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 comorbidity 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 weightings which are used in the Scottish HSMR model.

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 PHS has started collecting hospice data they are very incomplete.
**Base period**

A three-year dataset is used to create the risk-adjusted model, this three-year base period is dynamic and advanced by three months with each reporting period to ensure the predicted probabilities associated with patient case-mix is always representative of current outcomes and reflective of changing case-mix and provision of services.

**Reporting period**

The latest twelve-month period from the three-year base period is used to calculate the HSMR, and make comparisons against the national average.

**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)

• Comorbidities (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:

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

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

\[
\beta_0 = \text{coefficient on the constant term}
\]
The HSMR is calculated using a twelve-month period, as defined above. For each hospital \( h \) the HSMR is:

\[
HSMR_h = \frac{Observed\ Deaths_h}{Predicted\ Deaths_h}
\]

where,

\[
Observed\ Deaths_h = \sum_j Numberator_h
\]

the sum of patients who have died within 30-days of admission for hospital \( h \) over all case-mixes \( j \).

\[
Predicted\ Deaths_h = \sum_j Predicted\ Probabilities_h
\]

the sum of predicted probabilities for hospital \( h \) over all case-mixes \( j \).

To ensure that the baseline (i.e. Scottish SMR) is constant (i.e. 1.00), this needs to be adjusted for each reporting period. To achieve this each individual hospital SMR will be divided by the Scottish SMR for that period; adjusted predicted deaths will then be calculated by dividing observed deaths by the resulting ‘adjusted’ SMR for each hospital \( h \) as shown in the formulae below:

\[
Adjusted\ HSMR_h = HSMR_h / Scotland\ HSMR
\]

\[
Adjusted\ Predicted\ Deaths_h = Deaths_h / Adjusted\ HSMR_h
\]

Therefore, any improvements to an SMR value for a hospital compared to the previous publication will be relative to the Scottish average for the publication period. As a result, if the overall Scottish average has improved and the performance of a hospital has also improved around the same scale, their HSMR value should show little, if any, change.
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.

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.)

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.
References


Dr Foster Intelligence, 2014. Understanding HSMR - A Toolkit on Hospital Standardised Mortality Ratios.


Available at: https://pdfs.semanticscholar.org/78c4/50688e29d4e2b01da4acf8db88eb4a8334fe.pdf [Accessed 5th December 2018].


Available at:
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.

Specialties sheet describes how each of the individual specialty codes has been assigned to a specialty grouping variable.

Admission Type sheet describes how each of the type of admission codes has been assigned to an elective / non-elective variable.
Appendix 2 – Funnel plot

What is a funnel plot?

A funnel plot is a type of ‘Statistical Process Control’ chart that helps to show data at a particular point in time. Funnel plots in this report allow comparisons to be made between each hospital and the average for Scotland for a particular period.

The chart below provides an illustration of a funnel plot. The rate of the process, the HSMR, is plotted on the vertical axis. The denominator, predicted deaths, is plotted on the horizontal axis.

There are three lines in the funnel plots in this report.

The first line 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 three standard deviations from the average. Orange warning limits have also been plotted on the charts presented here, at two standard deviations from the average. In the example below data points presented as circles represent hospitals.
The limits are wider at the left hand side of the graph because the data points plotted here represent smaller hospitals which are made up of fewer observations and 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.

**Overdispersion**

An overdispersion factor has been applied to the funnel plot limits to reduce the effect of possibly false outliers. This is discussed in more detail in the Appendix 3.

**How to interpret a funnel plot**

Data points out with the control limits (referred to here as ‘outliers’) are said to exhibit ‘special cause variation’. Variations may reflect a number of factors, such as characteristics of the patients being cared for (case-mix), the quality of clinical care, errors in the data submitted by hospitals or even variation by chance. A single apparently high value of the HSMR is not sufficient evidence on which to conclude that a poor quality or unsafe service is being provided. This is why it is important not to focus solely on ‘outliers’ when making reliable judgements about the quality of patient care.
Appendix 3 - Adjusting funnel plot control limits for overdispersion

Overdispersion

Overdispersion ($\varphi$) occurs when there is true variability between hospitals, over and above what is expected due to random variation. This is usually due to factors which the model does not sufficiently correct for.

Unfortunately it can be difficult to identify in-control hospitals to estimate a $\varphi$ factor from. If we include the out of control hospitals we are likely to overestimate the $\varphi$ factor making it more difficult to detect the cases which you are interested in. To ensure estimates of the $\varphi$ factor are robust the influence of outlying cases that the system is designed to detect need to be minimised.

There are many ways to do this, one of which is to “Winsorise” the estimate.

Winsorising

Winsorising limits extreme values in the data to reduce the effect of possibly spurious outliers. There are many approaches to this e.g. the 10% largest z-scores are set to the 90% percentile and the 10% lowest z-scores are set to the 10% percentile, or setting the minimum and maximum z-scores to the second largest/ lowest z-scores. The latter approach is used to produce the estimate for $\varphi$ (i.e $\hat{\varphi}$) for HSMR funnel plot control limits.

Calculating overdispersion factor ($\hat{\varphi}$)

Calculate Standard Pearson residual (Z score), $Z_i$

$$Z_i = \frac{y_i - \theta_0}{\sqrt{\text{Var}(Y|\theta_0)}} = \frac{y_i - \theta_0}{\sigma} = \frac{\text{smr} - 1}{\sqrt{\text{scot_smr|expected}}}$$
Where, \( Y \) is the outcome measure and \( y_i \) the outcome for patient \( i \), \( \theta_0 \) the benchmark value. Standard Deviation \( \sigma = \sqrt{V(Y|\theta_0)} \)

Calculate winsorised Z score, \( Z^W \)

Rank cases according to \( Z_i \)

Identify minimum and maximum \( Z_i \) and reset to the next minimum and maximum values, creating \( Z \)

Calculate over-dispersion, \( \hat{\phi} \) using \( Z^W \)

\[
\hat{\phi} = \frac{1}{k} \sum_{i=1}^{n} Z_i^2
\]

Where, \( k \) is the number of hospitals. If \( \hat{\phi} = 1 \) there is no over-dispersion.

**Calculating lower and upper limits for funnel plot**

Upper/ Lower control limit = \( Y \pm 3.09 \times \sigma \times \sqrt{\hat{\phi}} \)

Upper/ Lower warning limit = \( Y \pm 1.96 \times \sigma \times \sqrt{\hat{\phi}} \)