Paper

HSMR 2014: Methodological report

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1. Introduction

For the fifth consecutive year (see CBS, 2011; 2012; 2013 and 2014), Statistics Netherlands (CBS) has calculated the Hospital Standardised Mortality Ratios (HSMRs) for Dutch hospitals. The current report describes the methods used for the HSMR 2012-2014. HSMRs are ratios of observed and expected number of deaths and aim to present comparable hospital mortality figures. The model as such has not changed compared to last year, but some minor changes have been implemented in the covariates. The covariate 'severity of the main diagnosis' has been recalculated resulting in less missing severities and small changes in the severities for some diagnoses. In addition, an update of the socio-economic status classification has been used for the 2014 data. More information on this can be found in appendix 1.

For the sake of clarity, this report is structured in the same way as the previous reports.

In this introductory chapter, section 1.1 describes the definition of the HSMR and the diagnosis specific SMR, section 1.2 examines the purpose of the HSMR and section 1.3 looks at its history. Authorisation was requested from the hospitals to deliver the HSMR figures (section 1.4). Section 1.5 presents an overview of the figures CBS has produced, and section 1.6 summarises some limitations of the HSMR as a quality indicator.

The methodological aspects of the model used to calculate the HSMRs are described in chapter 2. The model outcomes are evaluated in chapter 3. Chapter 4 deals with limitations of the HSMR, and possibilities for the future follow in chapter 5. Lastly, there are four appendices. Appendix 1 presents the definitions of the covariates (explanatory variables, predictors) used in the regression models. For various reasons no HSMRs are calculated for some hospitals. Appendix 2 gives the "exclusion criteria" for this. The results of the regression models are found in Appendix 3 and 4.

1.1 What is the (H)SMR?

Hospital mortality can be measured as the ratio of the number of hospital deaths to the number of hospital admissions (hospital stays) in the same period. This is generally referred to as the "gross mortality rate". Judging hospital performance on the basis of gross mortality rates is unfair, since one hospital may have had more life-threatening cases than another. For this purpose, it is more appropriate to adjust (i.e. standardise) mortality rates across hospitals as much as possible for differences in characteristics of the patients admitted to these hospitals ("case mix"). To this end, the *SMR* (Standardised Mortality Ratio) of a hospital *h* for diagnosis *d* is defined as

$$SMR_{dh} = 100 \times \frac{\text{Observed mortality}_{dh}}{\text{Expected mortality}_{dh}}.$$

The numerator is the *observed* number of deaths with main diagnosis *d* in hospital *h*. The denominator is the *expected* number of deaths for this type of admission under the assumption that individual mortality probabilities (per admission) do *not* depend on the hospital, i.e. are equal to mortality probabilities of identical cases in other hospitals. The denominator is therefore founded on a model based on data from all hospitals, in which the mortality of an admission is explained by characteristics of the patient, such as age, and characteristics of the admission, such as diagnosis and whether the admission is acute and unplanned versus

planned. Characteristics of the hospital, such as the number of doctors per bed, are generally not incorporated in the model, since these can be related to the quality of care in the hospitals, which is the intended outcome of the indicator. The model thus produces an expected (estimated) mortality probability for each admission. Adding up these probabilities per hospital gives the total expected mortality over all admissions of that hospital. For each diagnosis *d*, the average SMR_d across the hospitals equals 100 when each hospital is weighted with its (relative) expected mortality. Not all diagnoses are included in the calculation, only 50 "diagnosis groups *d*" that account for about 80% of entire hospital mortality. Day admissions are also excluded.

The *HSMR* of hospital *h* is defined as

$$HSMR_h = 100 \times \frac{\text{Observed mortality in } h}{\text{Expected mortality in } h}.$$

in which both the numerator and denominator are sums across all admissions for all considered diagnoses. The HSMR thus also has a weighted average of 100. As HSMRs may also deviate from 100 only by chance, confidence intervals of the SMRs and HSMRs are calculated so that hospitals can see whether they have a (statistically) significantly high or low adjusted mortality rate compared with the average of 100.

1.2 Purpose of the HSMR

As in many other countries, there is much interest in measuring the quality of health care in the Netherlands. Hospitals can be assessed using various quality indicators, such as the number of medical staff per bed or the availability of certain facilities. However, these indicators do not measure the outcomes of medical performance. A good indicator for the performance of a hospital is the extent to which its patients recover, given the diagnoses and other important characteristics, such as age, sex and comorbidity, of the patients. Unfortunately, recovery is hard to measure and mostly takes place after patients have been discharged from the hospital. Although hospital mortality is a much more limited quality indicator, it can be measured accurately. That is why this indicator is now used in several countries, using the HSMR and SMRs as defined in section 1.1. If these instruments were totally valid, i.e. the calculations could adjust perfectly for everything that cannot be influenced by the hospital, a value above 100 would always point to inferior care quality, and the difference between numerator and denominator could be considered an estimate of "avoidable mortality".[1] However, it is impossible to construct a perfect instrument to measure the quality of health care. A significantly high (H)SMR will at most be an indication of possible shortcomings in hospital care. But the high value may also be caused by coding errors in the data or the lack of essential covariates in the model related to mortality. Still, a significantly high (H)SMR is often seen as a warning sign, a reason for further investigation into the causes.

1.3 History of the HSMR

In 1999 Jarman initiated the calculation of the (H)SMR for hospitals in England (Jarman et al., 1999). In the following years the model for estimating mortality probabilities was improved by incorporating additional covariates into the model. Analogous models were adopted by some other countries.

[1] This would only be possible if the measurement was perfect and mortality by unforeseen complications, after adjustment for differences in case mix, was equally distributed across hospitals.

In 2005, Jarman started to calculate the (H)SMR for the Netherlands. Later on, these Dutch (H)SMRs were calculated by Kiwa Prismant, in collaboration with Jarman and his colleagues of Imperial College London, Dr Foster Intelligence in London and De Praktijk Index in the Netherlands. Their method is described in Jarman et al. (2010) and was slightly adapted by Kiwa Prismant (Prismant, 2008) up to reporting year 2009. In 2010 Dutch Hospital Data (DHD, Utrecht), the holder of the national hospital discharge data, asked CBS to calculate the (H)SMRs for the period 2008-2010 and for subsequent years. CBS is an independent public body and familiar with the input data for the HSMR, i.e. the hospital discharge register (LMR: Landelijke Medische Registratie, and its successor LBZ: Landelijke Basisregistratie Ziekenhuiszorg), as it uses this data source for a number of health statistics (see www.statline.cbs.nl).

The starting point for CBS was the HSMR methods previously used by Kiwa Prismant. As a result of progressive insight CBS introduced some changes in the model for the HSMR 2008-2010 (CBS, 2011), in close collaboration with, and largely based on the extensive research by the Dutch scientific HSMR Expert group set up by the hospital associations. With the exception of the first year that CBS produced the HSMR (2008-2010), the model has not undergone much change. In, 2013 the change from ICD9 to ICD10 resulted in some minor changes (see CBS, 2014). In 2014, the severities of the main diagnoses have been recalculated. This results in less missing severities and also resulted in a changes in the severities for some diagnoses.

1.4 Confidentiality

Under the Statistics Netherlands Act, CBS is required to keep all data about individuals, households, companies or institutions confidential. Therefore it normally does not deliver recognisable data from institutions to third parties, unless the institutions concerned have stated that they do not have any objections to this. For this reason, CBS needs written permission from all hospitals to deliver their hospital specific (H)SMR figures to DHD. In 2011, CBS and DHD together asked hospitals for such authorisation for a five-year period. In the following years, a request for authorisation was sent only to hospitals that had not previously authorised CBS and that participated in the LBZ/LMR. CBS only supplies DHD with (H)SMR outcomes of hospitals that have granted authorisation to do so. In turn DHD sends each hospital its individual outcome report. Publication of (H)SMR data, which has become mandatory in the Netherlands since 2014 by a regulation of the Dutch Healthcare Authority (NZa), is the responsibility of the hospitals themselves. CBS does not publish data on identifiable hospitals.

1.5 CBS output

CBS estimated the models for expected mortality per diagnosis for 2012-2014. It calculated the HSMRs and SMRs for all hospitals that (1) had authorised CBS, (2) had registered all or a sufficient part of its admissions in the LBZ/LMR in the relevant period, and (3) were not excluded on the grounds of criteria for quality and comparability, which means that the hospital's LBZ/LMR data were not too deviant in some respects (see Appendix 2).

CBS produces the following output:

1. A hospital-specific report for each hospital, sent via DHD, containing the HSMR and the diagnosis-specific SMR figures for 2012-2014 and the individual years. SMRs are also presented for different patient groups (by age, sex and urgency of admission) and diagnosis clusters. Hospitals can see how they compare with the national average, overall, and per diagnosis and patient group. CBS only made reports for hospitals not excluded under the exclusion criteria and that signed the authorisation request.

2. Each hospital not excluded on the grounds of the exclusion criteria and that signed the authorisation request is provided with a dataset with the mortality probabilities for all its admissions. Besides the probability, each record contains the observed mortality (0 or 1) and the scores on the covariates of the HSMR model. The hospital can use these data for internal investigation.
3. A report on the methods used for calculating the HSMR for 2012-2014 and separate years, including the model results and parameters (this document; see www.cbs.nl).

1.6 Limitations of the HSMR

In section 1.2 we argued that the HSMR is not the only indicator to measure hospital care quality. Furthermore, the quality and limitations of the HSMR (and the SMR) instrument are under debate. After all it is based on a statistical model (i.e. the denominator), and a model is always a simplification of reality. Chapter 4 elaborates on the limitations of the present HSMR instrument, which in summary are:

- Data quality is not uniform across hospitals. Van der Laan (2013) studied the impact of differences in the registration of the Charlson comorbidities and the urgency of the admission on the HSMR 2010. Differences between hospitals in the average number of registered Charlson comorbidities per admission are very large, even when adjusted for covariates like severity of the main diagnosis. It seems that a considerable part of these differences is due to variation in coding practice between hospitals. This harms the comparability of the HSMRs as the higher the number of comorbidities, the lower the HSMR. We observe an increase in the registration of Charlson comorbidities in the last few years, but probably there still is a need for greater consistency in coding practice (also see section 3.4).

- It is impossible to adjust perfectly for differences in case mix (the type of patients treated by a hospital) simply because patients are not randomised to hospitals. Some patient factors (related to mortality) are not coded in the LBZ/LMR and therefore cannot be included in the expected mortality model (denominator of the HSMR). So essential covariates are missing, and if the case mix differs too much between hospitals, standardisation cannot solve this problem completely.

- Hospitals differ not only in case mix, but also in the type of surgical procedures they are permitted to perform. Not all hospitals are authorised to perform high-risk interventions such as open heart surgery, for example. Therefore the HSMR of hospitals that have a licence to perform such interventions may be unjustly higher than that of hospitals that do not perform these interventions.

- Hospitals may differ in their admission and discharge policies, which can affect in-hospital mortality. One hospital may discharge patients earlier than another, for instance, because external terminal care facilities are available in the neighbourhood. Extending the period of hospital stay with a post-discharge period will diminish this problem (see chapter 5).

In addition to the above-mentioned limitations, the comparison of the (H)SMR results of 2013 and 2014 with those of previous years is less straightforward, partly because of the transition to ICD10 by most hospitals in 2013 (see CBS, 2014).

2. (H)SMR model

Expected hospital mortality - i.e. the denominator of the SMR - has to be determined for each diagnosis group. To this end we use logistic regression models, with mortality as the target (dependent) variable and various variables available in the LBZ/LMR as covariates. The regression models for the (H)SMR 2012-2014 and the (H)SMRs of the individual years use LBZ/LMR data for the last four years, i.e. the period 2011-2014. The addition of 2011 increases the stability and accuracy of the estimates, while keeping the model up to date. This procedure is identical to the one used for previous periods, when CBS also used models covering the most recent four-year period.

Compared to last year (CBS, 2014) there are no changes in the model itself. Only a minor change in the calculation of the `severity of main diagnosis' covariate has been implemented, and an update of the socio-economic status classification has been used for the 2014 data.

The classification of the 'severity of main diagnosis' is still based on ICD9-CM. More years of ICD10 coded hospital diagnoses are needed in the Netherlands before a new severity classification in ICD10 can be developed. Therefore the main diagnoses registered in ICD10 are converted to ICD9-CM to determine the severity covariate. The previous list of severities was only calculated for ICD9-CM diagnoses within the 50 CCS groups for which the HSMR is calculated. However, some ICD10 codes within the 50 CCS groups (defined in ICD10) convert to ICD9-CM codes that do not belong to these groups in ICD9-CM definitions. This has resulted in missing severities for these diagnoses. In the context of investigating the possible extension of the set of diagnosis groups for which the HSMR is calculated, the severities of the main diagnoses have now been calculated for all ICD9-CM codes. Furthermore, one more year (2010) is added to the data used in the calculation (all admissions from 2005-2010 have been used), and the threshold on the minimum number of admissions per ICD9-CM code and the number of hospitals using this code has been changed. This has resulted in more admissions with a severity of main diagnosis (different from 'Other'). More information on this can be found in appendix 1.

2.1 Target population and dataset

2.1.1 Hospitals

"Hospital" is the primary observation unit. Hospitals report admission data (hospital stay data) in the LBZ/LMR. However, not all hospitals participate in the LBZ/LMR.
In principle, the HSMR model includes all short-stay hospitals with inpatient admissions participating in the LBZ/LMR in 2011-2014. Of the specialised hospitals, only hospitals are included that have specialisms where patient mortality is likely to occur (hospitals for e.g. eye diseases are excluded). The target population of hospitals that qualify for entry in the HSMR-model thus includes all general hospitals (n=80), all university hospitals (n=8), and two short-stay specialised hospitals with inpatient admissions, which comes to a total of 90 hospitals. Three of these hospitals, 2 general hospitals and 1 specialised hospital, did not register any complete records of hospital admissions in the LBZ in 2014. The admissions of these hospitals cannot be analysed. Another 2 hospitals were partial non-respondents in 2014, in the sense that they only provided diagnosis information on part of their inpatient admissions. For the partial non-respondents only the completely registered LBZ admissions are included in the HSMR

model (with exceptions for some hospitals, see below). In total, the number of hospitals included in the HSMR model was 87 in 2014, 87 in 2013, 84 in 2012 and 86 in 2011.

For a number of partially non-responding hospitals only the fully registered months were included in the model, as in the other months there were indications that fatal cases were registered completely and non-fatal cases partially. The partially registered months of these hospitals were removed from the model as these would otherwise unjustly influence the estimates. For the years 2011 to 2014 this was done for 1, 4, 6 and 1 hospitals, respectively.

All the above-mentioned hospitals were included in the model, but (H)SMRs were only calculated for hospitals that met the criteria for LBZ/LMR participation, data quality and case mix (see Appendix 2).

2.1.2 Admissions

We considered both the population of hospitals and the population of admissions. Our target population of admissions consists of "all hospital stays (inpatient admissions) of Dutch residents in Dutch short-stay hospitals in a certain period". The date of discharge, and not the day of admission, determines the year a record is assigned to. So the 2014 population of hospital stays comprises all inpatient admissions that ended in 2014. For the sake of convenience, mostly we call these hospital stays "admissions", thus meaning the hospital stay instead of only its beginning. Day admissions are excluded as these are in principle non-life-threatening cases with hardly any mortality.

As many diagnoses have very low mortality, only the 50 diagnosis groups with the highest (absolute) mortality are analysed. These diagnosis groups (see section 2.3 for a further specification) account for 80.1% of entire inpatient hospital mortality and 36.7% of inpatient admissions in 2011-2014. Moreover, some registered admissions of a number of partially non-responding hospitals were excluded because of over-reporting of fatal cases (see section 2.1.1).

Lastly, admissions of foreigners are excluded from the HSMR model, partly in the context of possible future modifications of the model, when other data can be linked to admissions of Dutch residents. The number of admissions of foreigners is relatively small (27,696 inpatient admissions in 2011-2014) in the completely registered records.

Altogether, we included in the 2011-2014 model 2,387,686 inpatient admissions registered in the LBZ/LMR in the 50 CCS diagnosis groups.

2.2 Target variable (dependent variable)

The target variable for the regression analysis is the "in-hospital mortality". As this variable is binary, logistic regressions were performed.

The crude mortality rate for the population of 2,387,686 inpatient admissions mentioned in section 2.1 is 4.0%. But, of course, rates are different for different diseases.

2.3 Stratification

Instead of performing one logistic regression for all admissions, we performed a separate logistic regression for each of the selected diagnosis groups *d*. These sub-populations of admissions are more homogeneous than the entire population. Hence, this stratification may

improve the precision of the estimated mortality probabilities. As a result of the stratification, covariates are allowed to have different regression coefficients across diagnosis groups.
The diagnosis groups are clusters of ICD codes registered in the LBZ/LMR. Here the main diagnosis of the admission is used, i.e. the main reason for the hospital stay, which is determined at discharge. The CCS (Clinical Classifications Software[2]) is used for clustering: it clusters ICD diagnoses into a manageable number of clinically meaningful categories. For the HSMR, we selected the CCS groups with the highest mortality covering about 80% of total hospital mortality. The 50 CCS groups are listed in Table 5 in section 3.2. The ICD9-CM and ICD10 codes of these 50 CCS groups are available in a separate file published together with this report. The ICD9-CM definitions of the 50 CCS groups are used for the data up to 2012, and the ICD10 definitions are used for 2013 and later. The 50 CCS diagnosis groups have been kept constant over the last few years. Although the real "top 50" of CCS groups with highest mortality has changed slightly in the course of the years, for reasons of continuity CBS decided to use the same groups as Kiwa Prismant had. So the model includes 50 separate logistic regressions, one for each CCS diagnosis group *d* selected.

2.4 Covariates (explanatory variables or predictors of in-hospital mortality)

By including covariates of patient and admission characteristics in the model, the in-hospital mortality is adjusted for these characteristics. As a result, the (H)SMRs are adjusted for these covariates as well. Thus, variables (available in the LBZ/LMR) associated with patient in-hospital mortality are chosen as covariates. The more the covariates discriminate between hospitals, the larger the effect on the (H)SMR.

The following LBZ/LMR variables are included in the model as covariates:

- Age at admission (21 categories);
- Sex of the patient (2 categories);
- SES (socio-economic status) of the postal area of the patient's address (6 categories). The SES classification per postal code is compiled by the Netherlands Institute for Social Research (SCP). For 2014 updated data from SCP were used for the SES scores per postal code.
- Severity of main diagnosis (9 categories). Instead of CCS diagnosis subgroups, we used a classification of severity of the main diagnosis in terms of mortality rates, as suggested by Van den Bosch et al. (2011); see Appendix 1.
- Urgency of admission (elective, acute);
- Comorbidity_1 – Comorbidity_17, i.e. a separate dummy variable (indicator variable) for each of the 17 comorbidity groups that make up the "Charlson index". The groups are listed in Table A1.1 in Appendix 1. Up to 2012 the ICD9-CM definitions of the Charlson comorbidities were used. For 2013 and later CBS used a new set of ICD10-definitions, which were determined after a literature review of the available ICD10 translations.
  Each dummy variable indicates whether the patient suffers from the specific comorbidity (e.g. diabetes), based on the secondary diagnoses registered in the LBZ/LMR. The procedure with separate dummy variables instead of the Charlson index was suggested by Lingsma and Pouw, who did research for the Dutch HSMR Expert group; see Appendix 1.

[2] *See http://www.hcup-us.ahrq.gov/toolssoftware/icd_10/ccs_icd_10.jsp*

- Source of admission (3 categories: home, nursing home or other institution, hospital), indicating the patient's location before the admission; see Appendix 1.
- Year of discharge (4 categories: 2011-2014);
- Month of admission (6 categories of two months).

More information about these covariates and their use in the analysis is given in Appendix 1. Non-significant covariates are preserved in the model, unless the number of admissions is smaller than 50 (or if there are no deaths) for all but one category of a covariate; see section 2.5.2. The inclusion of "Year of discharge" in the model guarantees that the SMRs and HSMRs have an average of 100 for all years.

2.5 Computation of the model and the (H)SMR

2.5.1 SMR and HSMR

According to the first formula in section 1.1, the SMR of hospital *h* for diagnosis *d* is written as

$$SMR_{dh} = 100\frac{O_{dh}}{E_{dh}} \tag{2.1}$$

with O_{dh} the observed number of deaths with diagnosis *d* in hospital *h*, and E_{dh} the expected number of deaths in a certain period. We can denote these respectively as

$$O_{dh} = \sum_i D_{dhi}, \tag{2.2}$$

and

$$E_{dh} = \sum_i \hat{p}_{dhi}, \tag{2.3}$$

where D_{dhi} denotes the observed mortality for the i^{th} admission of the combination (*d*,*h*), with scores 1 (death) and 0 (survival), and $\hat{p}_{dhi}$ the mortality probability for this admission, as estimated by the logistic regression of "mortality diagnosis *d*" on the set of covariates mentioned in section 2.4 This gives

$$\hat{p}_{dhi} = \text{Prob}(D_{dhi} = 1|X_{dhi}) = \frac{1}{1+\exp(-\hat{\beta}_d' X_{dhi})}, \tag{2.4}$$

with X_{dhi} the scores of admission *i* of hospital *h* on the set of covariates, and $\hat{\beta}_d$ the maximum likelihood estimates of the corresponding regression coefficients, i.e. the so-called log-odds. For the HSMR of hospital *h*, we have accordingly

$$\text{HSMR}_h = 100\frac{O_h}{E_h} = 100\frac{\sum_d O_{dh}}{\sum_d E_{dh}} = 100\frac{\sum_d \sum_i D_{dhi}}{\sum_d \sum_i \hat{p}_{dhi}}. \tag{2.5}$$

It follows from the above formulae that:

$$\text{HSMR}_h = 100\frac{\sum_d E_{dh}\frac{O_{dh}}{E_{dh}}}{E_h} = \sum_d \frac{E_{dh}}{E_h}\text{SMR}_{dh}. \tag{2.6}$$

Hence, an HSMR is a weighted mean of the SMRs, with the expected mortalities across diagnoses as the weights.

2.5.2 Modelling and model-diagnostics

We estimated a logistic regression model for each of the 50 CCS diagnosis groups, using the categorical covariates mentioned in section 2.4 and in Appendix 1. The latter also gives an overview of their categories. Categories, including the reference category, are collapsed if the number of admissions is smaller than 50, to prevent standard errors of the regression coefficients becoming too large. This collapsing is performed starting with the smallest category, which is combined with the smallest nearby category, etc. For variables with only two categories collapsing results in dropping the covariate out of the model (except for comorbidities 17 (Severe liver disease) and 11 (Diabetes complications) which are first combined with comorbidity 9 (Liver disease), and comorbidity 10 (Diabetes), respectively; see Appendix 1). For technical reasons connected with the chosen R-software, collapsing also took place when there were no deaths in the category. All regression coefficients are presented in the file "Coefficients HSMR 2014.xls" published together with this report.

The following statistics are presented to evaluate the 50 models:

- *standard errors* for all regression coefficients (file "Coefficients HSMR 2014.xls");
- *statistical significance* of the covariates with significance level α=.05, i.e. confidence level .95 (Table A3.1);
- *Wald statistics* for the overall effect and the significance testing of categorical variables (Table A3.2);
- *C-statistics* for the overall fit. The C-statistic is a measure for the predictive validity of, in our case, a logistic regression. Its maximum value of 1 indicates perfect discriminating power and 0.5 discriminating power not better than expected by chance, which will be the case if no appropriate covariates are found. We present the C-statistics as an evaluation criterion for the 50 logistic regressions; see Table 5 in section 3.2.

Summaries of the statistical significance and the Wald statistics are presented in Tables 2 and 3 in section 3.1. In addition to these diagnostic measures for the regressions, we present the *average shift in HSMR* by inclusion/deletion of the covariate in/from the model (Table 4 in section 3.1). This average absolute difference in HSMR is defined as

$$\frac{1}{N}\sum_{h=1}^{N}\left|\mathrm{HSMR}_h - \mathrm{HSMR}_h^{-x_j}\right|, \tag{3.1}$$

where $\mathrm{HSMR}_h^{-x_j}$ is the HSMR that would result from deletion of covariate x_j, and N=81 the total number of hospitals for which an HSMR was calculated for 2014.

A high Wald statistic implies that the covariate's categories discriminate in mortality rates. But if the frequency distribution of the covariate is equal for all hospitals, the covariate would not have any impact on the (H)SMRs. Therefore we also present the change in HSMRs resulting from deleting the covariate. Of course, a covariate that only has low Wald statistics has little impact on the (H)SMRs.

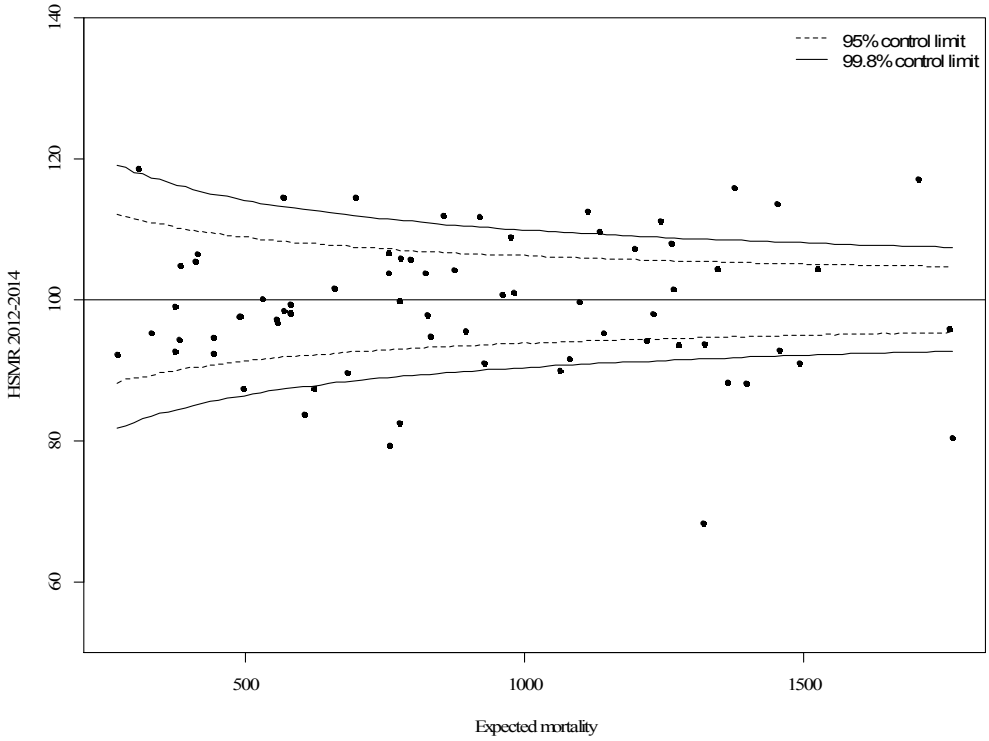
2.5.3 Confidence intervals and control limits

A 95% confidence interval is calculated for each SMR and HSMR, i.e. an upper and lower confidence limit. These limits are mentioned in the specific reports for the hospitals. A lower limit above 100 indicates a statistically significant high (H)SMR, and an upper limit below 100 a statistically significant low (H)SMR. In the calculation of these confidence intervals, a Poisson distribution is assumed for the numerator of the (H)SMR, while the denominator is assumed to have no variation. This is a good approximation, since the variance of the denominator is small. As a result of these assumptions, we were able to compute exact confidence limits.

HSMRs can be presented in a funnel plot (see Figure 1): a plot of hospitals, where the vertical axis represents the HSMRs and the horizontal axis the expected mortalities. Hospitals located above the horizontal axis (HSMR=100) have a higher than expected mortality. As this might be a non-significant feature, based on chance, control limits are shown in the plot for each possible expected mortality. HSMRs within these control limits do not deviate significantly from 100. In the case of 95% control limits, about 2.5% of the points would lie above the upper limit if there is no reason for differences between HSMRs, and about 2.5% of the points below the lower limit. The same holds, mutatis mutandis, for the 99.8% control limits. Here about 0.1% of the points would be located above the upper line if there is no reason for differences in standardised mortality rates. Most attention will be paid to this line, as points above this line have a high HSMR that is statistically very significant, which can hardly be the result of chance alone. These hospitals would be advised to investigate the possible reasons for the significantly high values: coding errors, unmeasured case mix variables and/or suboptimal quality of care.

Figure 1 presents the funnel plot of the HSMRs for 2012-2014, with exact control limits. As mentioned before, some hospitals were excluded on the grounds of criteria for quality and comparability. Hospitals that did not authorise CBS to calculate their HSMRs were excluded too. As some of these hospitals are still represented in the expected mortality model, the (weighted) average HSMR of the displayed hospitals will not exactly equal 100: for 2012-2014 it is 99.0 (n=71 hospitals). For the year 2014 the average HSMR of the non-excluded hospitals (n=82) is 100.2. Restriction of the models to the non-excluded hospitals would not have changed the general picture in the funnel plot, apart from the small effect on the HSMR averages.

Figure 1. Funnel plot HSMR 2012-2014



The precision of the HSMR is much greater for a three-year period than for a single year, as reflected by the smaller range between the control limits. The confidence intervals of the HSMR are also smaller. Of course, drawbacks are that two consecutive three-year figures (e.g. 2011-2013 and 2012-2014) overlap, and that the three-year figure is less up-to-date than the figure of the last year. Therefore we also calculated the figures for the last available year (funnel plot of 2014 not presented here). Observed mortality (numerator) and expected mortality (denominator) are then calculated for the 2014 admissions, whereas the expected mortality model of the HSMR still uses the 2011-2014 data. If a hospital has a significantly high HSMR in 2014, but not for 2012-2014, this is a signal for further investigation, as the quality of care may have deteriorated. On the other hand, if a hospital has a significantly high HSMR in 2012-2014, but not in 2014, this does not necessarily mean that the situation improved in 2014, as the one-year figures are less often significant because of the larger margins. In such cases, not only the significance should be taken into account, but also the HSMR levels over the years.

3. Model results and evaluation

This chapter presents and evaluates the model results. Some summary measures of the 50 logistic regressions are presented, one for each CCS group, with inpatient mortality as the dependent variable and the variables mentioned in section 2.4 as explanatory variables. More detailed results are presented in Appendix 3, and the regression coefficients and their standard errors in the file "Coefficients HSMR 2014.xls".

The computations were performed using the `lrm` procedure of the R-package `rms`.

3.1 Impact of the covariates on mortality and HSMR

Table A3.1 of Appendix 3 shows which covariates have a statistically significant (95% confidence) impact on in-hospital mortality for each CCS diagnosis group: "1" indicates (statistical) significance, and "0" non-significance, while a dash (-) means that the covariate has been dropped as the number of admissions is smaller than 50 (or as there are no deaths) for all but one category of a covariate; see section 2.5.2. The last row of Table A3.1 gives the numbers of significant results across the CCS groups for each covariate. These values are presented again in Table 1 below, as a summary, but ordered by the number of times a covariate is significant. Age, urgency of the admission, severity of the main diagnosis and year of discharge are significant for the great majority of the 50 diagnosis groups. This is also true for several of the comorbidity groups, especially groups 2, 13, 9 and 16, i.e. for Congestive heart failure, Renal disease, Liver disease and Metastatic cancer. Comorbidity group 9 (liver disease) and year of discharge have risen somewhat compared to previous year. Comorbidity 15, HIV, was not significant for any of the CCS groups. It was seldom registered as a comorbidity; most CCS groups had fewer than 50 admissions with HIV comorbidity. In general the number of significant parameters for the comorbidities has increased slightly. This is probably caused by the general increase in comorbidity coding (see section 3.4). This was also seen previous years (see CBS, 2013 and 2014).

Table 1. Statistical significance of the covariates for the 50 logistic regressions (summary), HSMR 2014 model

Covariate	No. of significant results	Covariate	No. of significant results
Comorbidity_2	49	Comorbidity_1	34
Age	48	Comorbidity_5	30
Comorbidity_13	47	Sex	25
Comorbidity_9	46	Comorbidity_17	23
Comorbidity_16	46	Comorbidity_10	19
Urgency	44	Comorbidity_11	19
Year of discharge	44	Month of admission	16
Severity main diagnosis	43	Comorbidity_8	13
Comorbidity_4	40	Comorbidity_12	12
Comorbidity_6	40	Comorbidity_7	11
Comorbidity_14	40	SES	10
Comorbidity_3	38	Comorbidity_15	0
Source of admission	38		

The relative impact of the covariates on mortality is expressed better by the Wald (chi-square) statistics for each covariate; see Table A3.2A of Appendix 3. The Wald statistic was used to test whether the covariates had a significant impact on mortality. But it can also be used as a measure of association. A large value of a Wald statistic points to a strong impact of that covariate on mortality, adjusted for the impact of the other covariates. It is a kind of "explained chi-square". As the number of categories may "benefit" covariates with many categories, the corresponding numbers of degrees of freedom (df) are presented in Table A3.2B, where df is the number of categories minus 1. As a result of collapsing of categories - when a category has fewer than 50 admissions or has no deaths - df can be smaller than the original number of categories minus 1. Hence, Age may have its maximum of 20 df, as it has 21 categories, but if categories are collapsed, df will be smaller than 20. A covariate will disappear from a regression if all its categories are collapsed. This happens frequently for several of the comorbidities, and incidentally for Sex (for cancer of prostate) and Severity of main diagnosis (when all subdiagnoses of the CCS main diagnosis group fall in the same severity category). For Severity of main diagnosis, df also depends on the CCS main diagnosis group, as the (severity of) subdiagnoses differ, resulting in different numbers of categories.

The last row of Table A3.2A gives the sum of the Wald statistics across the 50 regressions for each covariate, as a kind of overall explained chi-square. In Table 2 below, these are presented again, as a summary, but ordered by value, and with the sums of degrees of freedom, the last row of Table A3.2B. It shows that severity of main diagnosis has the highest explanatory power, with 22,423 as the sum of the Wald statistics. Age and urgency of admission are also important variables. The explanatory powers of Month of admission, Sex and SES are relatively small. This is also true for some comorbidity groups. Comorbidity groups 2, 13 and 16 are the groups with the most impact on mortality. The sum of all Wald statistics for the 17 comorbidity groups considered equals 22,473 with 724 df, but because of interference of comorbidities this is only an indication of their combined effect. In any case, it can be concluded that several comorbidity groups also make an important contribution to the model.

Table 2. Wald chi-square statistics for the 50 logistic regressions, HSMR 2014 model

Covariate	Sum of Wald statistics	Sum of df	Covariate	Sum of Wald statistics	Sum of df
Severity main diagnosis	22423	143	Comorbidity_3	1031	50
			Comorbidity_1	832	50
Age	19839	765	Comorbidity_17	645	24
Urgency	11834	50	Comorbidity_5	552	46
Comorbidity_2	6987	50	Month of admission	536	250
Comorbidity_16	3468	49	Sex	501	49
Comorbidity_13	2656	50	SES	348	230
Year of discharge	1943	150	Comorbidity_10	259	50
Source of admission	1493	100	Comorbidity_12	216	35
Comorbidity_9	1403	49	Comorbidity_11	206	45
Comorbidity_6	1373	50	Comorbidity_7	178	47
Comorbidity_14	1316	50	Comorbidity_8	169	26
Comorbidity_4	1178	49	Comorbidity_15	4	4

As mentioned before, Table 2 is only a summary of Table A3.2. The effect of a covariate on mortality may be very different for different CCS groups.

Table 3 shows the impact of each covariate on the HSMR 2014, as measured by formula (3.1) for the 82 hospitals for which HSMRs are calculated. Age and Severity of the main diagnosis had the largest effect on mortality (for the years 2011-2014), but their impact on *hospital* mortality is smaller, apparently as a result of relatively small differences in their distributions between hospitals. Comorbidity discriminates much more between hospitals. This is caused by differences in case mixes, but possibly also by differences in coding practice. Notice that we consider the comorbidities as one group here. Deleting Sex has hardly any impact on the HSMRs. Compared to Sex, SES has a reasonable impact on the HSMR 2014. This is because hospitals differ more in terms of SES categories of the postal areas in their vicinity than in terms of the sex distribution of their patients. Compared to last year the impact of 'source of admission' has increased significantly (from 0.76 to 1.78). That of 'month of admission' has decreased (from 0.66 to 0.14). Although some covariates do not have much impact on the HSMRs, it is still worth keeping them in the model because of their impact on mortality and because the distributions of the covariates between hospitals may change over time.

Table 3. Average shift in HSMR 2014 by inclusion/deletion of covariates

Covariate	Average shift in HSMR	Covariate	Average shift in HSMR
Comorbidity [a)]	8.50	Source of admission	1.78
Age	5.05	SES	0.95
Urgency	2.95	Month of admission	0.14
Severity main diagnosis	2.54	Sex	0.12

a) The comorbidities were deleted as one group and not separately.

3.2 Model evaluation for the 50 regression analyses

Table 4 presents numbers of admissions and deaths, and C-statistics for the 50 CCS diagnosis groups. The C-statistic is explained in section 2.5.2. The C-statistics do not differ much from the figures for the previous year (CBS, 2014). For most diagnosis groups (31/50) the C-statistic has slightly increased (average increase 0.004). For "Cancer of pancreas", "Coma; stupor; and brain damage", "Coronary atherosclerosis and other heart disease" and "Acute myocardial infarction" the increase was larger than 0.02 (0.026-0.037). "Intracranial injury" and "Leukaemias" decreased by more than 0.02 (0.021 and 0.035 respectively). All C-statistics except two are between 0.7 and 0.94. The two below 0.7 are "Aspiration pneumonitis; food/vomitus" and "Congestive heart failure; nonhypertensive". For these diagnoses the model is only partially able to explain patient mortality. For the highest scoring diagnosis groups (above 0.9) the covariates strongly reduce the uncertainty in predicting patient mortality.

Table 4. C-statistics for the logistic regressions of the 50 CCS main diagnosis groups

CCS-group no	Description CCS diagnosis group	Number of admissions	Number of deaths	C-statistic
2	Septicemia (except in labour)	21558	5521	0,75
12	Cancer of esophagus	9621	564	0,78
13	Cancer of stomach	13091	551	0,80
14	Cancer of colon	41928	1501	0,82
15	Cancer of rectum and anus	21758	549	0,81
17	Cancer of pancreas	12946	794	0,78
19	Cancer of bronchus; lung	71921	4517	0,84
24	Cancer of breast	51733	400	0,94
29	Cancer of prostate	22948	444	0,92
32	Cancer of bladder	42126	425	0,90
38	Non-Hodgkins lymphoma	19919	882	0,83
39	Leukaemias	20618	1177	0,80
42	Secondary malignancies	74371	4216	0,79
44	Neoplasms of unspecified nature or uncertain behaviour	15257	278	0,84
50	Diabetes mellitus with complications	27219	422	0,86
55	Fluid and electrolyte disorders	27695	782	0,84
59	Deficiency and other anaemia	44417	412	0,80
85	Coma; stupor; and brain damage	3904	502	0,84
96	Heart valve disorders	34235	1069	0,79
100	Acute myocardial infarction	101791	4396	0,80
101	Coronary atherosclerosis and other heart disease	174161	1179	0,83
103	Pulmonary heart disease	29584	1052	0,80
106	Cardiac dysrhythmias	168133	1056	0,87
107	Cardiac arrest and ventricular fibrillation	9770	3938	0,75
108	Congestive heart failure; nonhypertensive	99904	8983	0,67
109	Acute cerebrovascular disease	102845	11620	0,79
114	Peripheral and visceral atherosclerosis	33779	1594	0,91
115	Aortic; peripheral; and visceral artery aneurysms	26718	2527	0,89
116	Aortic and peripheral arterial embolism or thrombosis	25724	552	0,88
117	Other circulatory disease	25790	550	0,87
122	Pneumonia (except that caused by tuberculosis or sexually transmitted diseases)	124038	9321	0,78
127	Chronic obstructive pulmonary disease and bronchiectas	100641	4245	0,71
129	Aspiration pneumonitis; food/vomitus	5485	1331	0,69
130	Pleurisy; pneumothorax; pulmonary collapse	23282	697	0,84
133	Other lower respiratory disease	66159	2250	0,86
145	Intestinal obstruction without hernia	31207	1492	0,84
146	Diverticulosis and diverticulitis	36137	503	0,87
149	Biliary tract disease	128644	652	0,91
150	Liver disease; alcohol-related	5629	702	0,72
151	Other liver diseases	16061	908	0,82
153	Gastrointestinal haemorrhage	33255	1035	0,81
155	Other gastrointestinal disorders	48606	660	0,92
157	Acute and unspecified renal failure	14917	1070	0,78
158	Chronic renal failure	15329	509	0,87
159	Urinary tract infections	71706	1575	0,82
226	Fracture of neck of femur (hip)	65244	2224	0,80
233	Intracranial injury	52549	1809	0,91
237	Complication of device; implant or graft	87536	1075	0,86
238	Complications of surgical procedures or medical care	83605	1036	0,87
249	Shock	2192	986	0,73

3.3 Regression coefficients

The file "coefficients HSMR 2014.xls" contains the estimated regression coefficients (columns "Estimate"), also called "log-odds", for each of the 50 logistic regressions, as well as their standard errors (columns "Std. Err."). The estimated regression coefficients are the elements of the vector $\hat{\beta}_d$ in formula (2.4), for each diagnosis *d*. Notice that a β-coefficient has to be interpreted as the difference in log-odds between the category in question and the reference category (first category of the same covariate). For the sake of clarity, the reference categories are given in the first row of the corresponding covariates, and by definition have zero coefficient for each regression. In many cases categories are collapsed (see section 2.5.2). This results in equal coefficients for the collapsed categories. If all categories were collapsed into one category for a certain variable and for a certain CCS group (i.e. if there was only one category with ≥50 admissions and ≥1 death), the variable was dropped from the model and all associated coefficients are set to zero.

3.4 Development in the coding of comorbidities

Table 5 clearly shows that the average number of registered comorbidity codes per admission nationwide has almost tripled since 2009. In 2014 hospitals coded on average 0.7 comorbidities per admission. There seems to be more attention to proper coding of comorbidities which is a positive development. However, previous studies (Van der Laan, 2013) have also shown that the variation between hospitals is greater than one would expect and that this variation introduces extra noise in the HSMR. As stated in section 3.1 the comorbidities are an important set of covariates in the models used to calculate the HSMR.

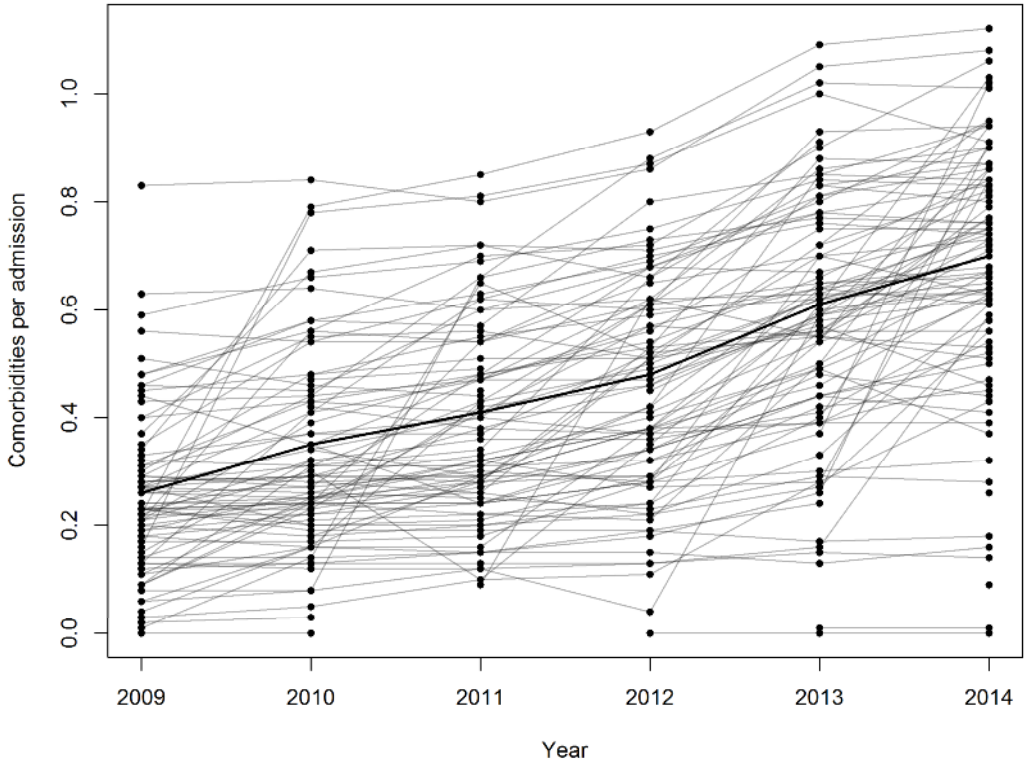
Table 5. Registered Charlson comorbidities per inpatient admission in the 50 CCS groups, 2009-2014

Year	2009	2010	2011	2012	2013	2014
Average number of comorbidities per admission	0.26	0.35	0.41	0.48	0.61	0.70

Figure 2 shows the annual development in the average number of comorbidities per admission for each of the hospitals. The overall trend is clearly visible. In addition, each year there is a group of hospitals for which the number of comorbidities coded has shot up. This is probably because these hospitals focus more on the coding of comorbidities. There also appears to be a small group of hospitals which code very few comorbidities and which also show no increase.

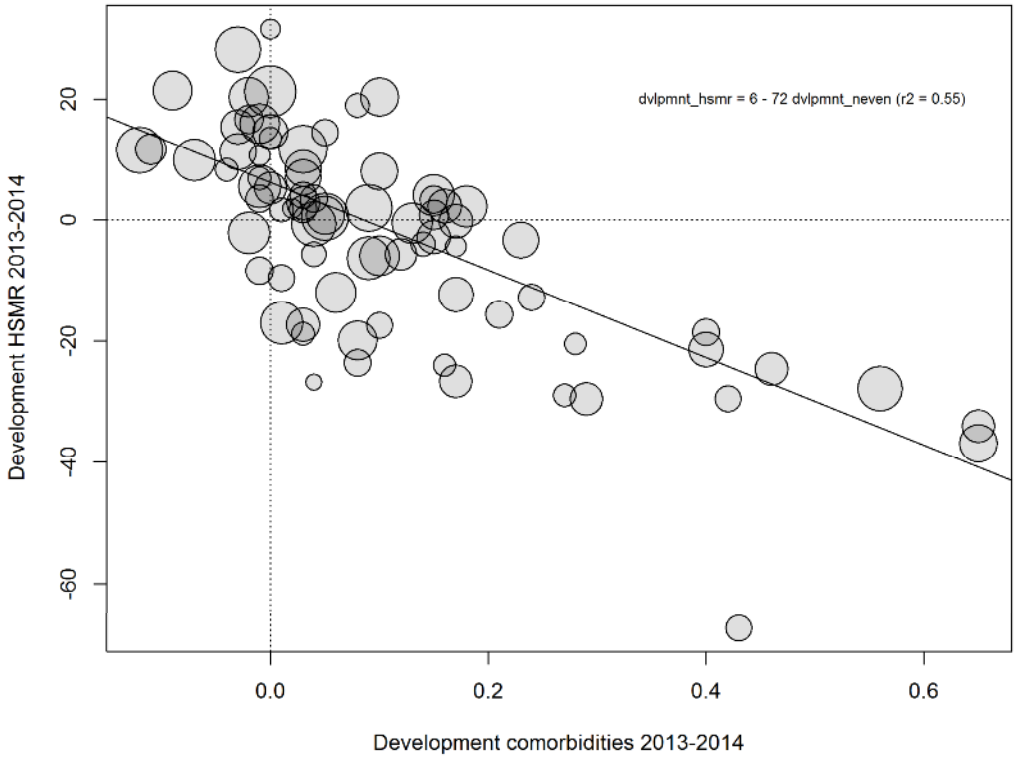
For the first time since 2009 the variance in the registered comorbidities has not increased in 2014 and when the stragglers and other hospitals with known coding issues are removed from the analysis the variance in 2014 has even decreased compared to 2013 (data not shown).

Figure 2. Developments in the average number of comorbidities per admission for each of the hospitals. The thick solid line shows the overall average.



Although the overall situation seems to be improving, the variation in the number of coded comorbidities is still partly caused by differences in coding and not by actual differences in the patient population between the hospitals. Therefore, differences in coding still cause noise in the HSMR. Figure 3 shows the development in the HSMR from 2013 to 2014 for each of the hospitals plotted against the development in the number of coded comorbidities. The figure clearly shows that hospitals that have increased their number of registered comorbidities tend to have a decrease in their HSMR. Furthermore, we see a slight average increase in the HSMR for hospitals that have coded the same number of comorbidities in 2014 as in 2013. This is to be expected, as the average number of comorbidities coded per admission has increased. Because of this, the patient populations of hospitals that have remained constant have become relatively 'lighter' which causes the expected mortality to decrease and consequently the HSMR to increase. Therefore, part of the developments in the HSMRs of individual hospitals are caused by developments in coding and not by development in quality of care.

Figure 3. Development in the HSMR from 2013 to 2014 compared to the development in the average number of comorbidities per inpatient admission for each of the hospitals. The circles are proportional to the size of the hospitals. The solid line shows the weighted regression line through these points.



4. Limitations of the HSMR

Since the very first publication of the HSMR in England, there has been an on-going debate about the quality of the HSMR as an instrument. Supporters and opponents agree that the HSMR is not a unique, ideal measure, but at most a possible indicator for the quality of health care, alongside other possible indicators. But even if HSMR were to be used for a more limited purpose, i.e. standardising hospital mortality rates for unwanted side-effects, the interpretation of HSMRs would present various problems, some of which are described briefly below. See also Van Gestel et al. (2012) for an overview.

- Appendix 1 contains the list of covariates included in the regression model. Hospitals do not always code these variables in the same way. Variables such as Age and Sex do not give any problems, but how aspects like acute admissions, main diagnosis and comorbidity are coded may depend on individual physicians and coders. Lilford and Pronovost (2010) argue that if the quality of the source data is insufficient, the regression model should not adjust for such erroneously coded covariates. Our own investigation (Van der Laan, 2013; and section 3.4) shows that comorbidities in particular present a problem, as there is not much uniformity in coding this covariate so far. Van den Bosch et al. (2010) refer extensively to the influence of coding errors. Exclusion criteria for outliers may solve this problem in part but not completely.

- Some hospitals may have on average more seriously ill patients than others, even if they have the same set of scores on the covariates. University hospitals may, for example, have more serious cases than other hospitals. It is questionable whether the model adjusts satisfactorily for this phenomenon. Some essential covariates related to mortality are then missing. This may be caused by some of the desired covariates not being measured in the LBZ/LMR. Some factors will actually even be hard to measure in this type of routinely collected datasets of all hospital discharges.

- The same problem occurs when certain high risk surgical procedures are only performed in certain hospitals. For instance, open heart surgery only occurs in authorised cardiac centres, and these hospitals may have higher SMRs for heart disease because of the more dangerous interventions. This could be solved by including a covariate in the model that indicates whether such a procedure was performed. This has the disadvantage that a method of treatment is used as a covariate, while ideally it should not be part of the model as it is a component of hospital care. Another - practical - problem is that the registration of surgical procedures in the LBZ/LMR has been far from complete in recent years.

- Hospital admission and discharge policies may differ. For instance, one hospital may admit the same patient more frequently but for shorter stays than another. Or it may discharge a patient earlier than another because there are adequate external terminal care facilities in the neighbourhood. Moreover, hospitals may also allocate health care differently, paying more or less attention to less acute cases. Obviously, all these situations influence the outcome of the HSMR, as they influence the observed mortality numbers, but these differences in HSMR cannot be translated in terms of quality of care.

Hospitals can compare their HSMR and SMRs with the national average of 100. The comparison between (H)SMRs of two or more hospitals with each other is more complicated. There is no complete adjustment for differences in case mix between pairs of hospitals. Theoretically, it is even possible that hospital A has higher SMRs than hospital B for all diagnosis groups, but a lower HSMR. Although this is rather theoretical, bilateral comparison of HSMRs should be undertaken with caution (Heijink et al., 2008).

5. Possibilities for the future

An indicator including early post-discharge mortality alongside in-hospital mortality could be introduced to tackle the problem of range in availability of terminal care outside hospital. Ploemacher *et al*. (2013) saw a decrease in standardised in-hospital mortality in the Netherlands in 2005-2010, which may have been caused by an overall improvement in care quality, but may also be partly explained by substitution of in-hospital mortality by outside-hospital mortality, possibly caused by changes in hospital admission and discharge policies. In cooperation with CBS, Pouw *et al*. (2013) did a retrospective analysis on Dutch hospital data linked to mortality data, and concluded that including early post-discharge mortality is advisable to diminish the effect of discharge bias on the HSMR. In the UK, the SHMI (Summary Hospital-level Mortality Indicator) has been adopted, which includes mortality up to 30 days after discharge (Campbell *et al*., 2011). In 2014, CBS studied the optimal time frame and definition of an indicator including early post-discharge mortality (Van der Laan *et al*., 2014). A fixed period of 45 days after admission in which all mortality is included in the mortality indicator, would make the indicator less dependent on hospital discharge policies. A recent French study also recommends fixed post-admission periods of more than 30 days (Lamarche-Vadel et al., 2015).

Although including post-discharge mortality in the indicator would reduce the effect of differences in hospital discharge policies, it would not reduce the effect of differences in admission policies for terminally ill patients. Some hospitals may admit more patients specifically (and sometimes only) for palliative care than other hospitals. As such patients are admitted to die in hospital, not to receive curative care, these admissions may distort HSMR outcomes. Palliative care can be measured in ICD10 (code Z51.5), but this variable should be used with caution, as differences between hospitals in coding practices have been shown in UK and Canada, and adjusting for palliative care may increase the risk of gaming (NHS, 2013; Chong et al., 2012; Bottle et al., 2011). Because of this, and because the LBZ/LMR registration does not allow for distinguishing between admissions of terminally ill patients for palliative care only and admissions for curative treatment ending in palliative care, palliative care admissions have not yet been excluded from the calculation of the HSMR in the Netherlands. However, the HSMR reports sent to the hospitals include information on the percentage of the hospital's admissions and deaths related to palliative care as registered in the LBZ/LMR compared to the overall average. This may indicate to some extent whether or not palliative care could have biased a hospital's HSMR. However, since the Netherlands also shows a large variation between hospitals in the coding of palliative care, this information should be used with caution.

Currently, Statistics Netherlands is studying the possible extension of the set of diagnosis groups included in the HSMR. The fifty diagnosis groups currently used cover approximately 80 percent of hospital mortality and approximately 36 percent of all hospital admissions. Two options are investigated. First, to extend the current set so that for instance 90 percent of mortality is covered. Second, to include all hospital admissions. A disadvantage of including all mortality is that the indicator also includes diagnosis groups with very low mortality. The advantage is that the indicator describes all hospital mortality, which improves the interpretation of the indicator.

In 2014, the Dutch Healthcare Authority (NZa) introduced a new type of care: 'acute in-hospital patient observations lasting at least 4 hours, but without overnight stay'. Unlike day cases these are unplanned observations, for example, of patients coming to the emergency ward with health problems. Mortality does occur in these types of 'admissions'. Up until mid-2014

hospitals were not required to register these observations in the LBZ/LMR. As a result the registration of this type of admission was not complete in 2014, and therefore the observations were not included in the (H)SMR. In plan in future, when there is a complete registration of the observations, is to include these in the (H)SMR.

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Appendix 1. Covariates: definitions and use in regression analyses

This appendix presents more detailed information on the definitions and categories of the covariates, and their use in the regression analyses.

In 2011, only a few hospitals started coding diagnoses in ICD10; in 2012, 38 out of 84 hospitals coded all or part of their diagnoses in ICD10. For 2012 and earlier, diagnoses coded in ICD10 were converted to their ICD9-CM equivalents for the HSMR calculation. As almost all hospitals (80 of the 87 in the HSMR model) coded diagnoses in ICD10 in 2013, from this year onwards the CCS diagnosis groups and the Charlson comorbidities are determined directly from the registered ICD10 codes. The severity of the main diagnosis is still derived from the ICD9-CM code, as the severity classification is based on historical data coded in ICD9-CM.
Therefore the main diagnoses registered in ICD10 were converted to ICD9-CM to determine the severity covariate. On the other hand, for the few hospitals that registered in ICD9-CM in 2013 diagnoses were converted to ICD10 to derive the main diagnosis groups and the Charlson comorbidities. For the conversion of ICD10 to ICD9-CM we used conversion table 'ICD-10 – CvZ80'; for the conversion of ICD9-CM to ICD10 we used conversion table 'CvZ80 – ICD-10', see http://www.rivm.nl/who-fic/ICD.htm.

For the regressions, all categorical covariates are transformed into dummy variables (indicator variables), having scores 0 and 1. A patient scores 1 on a dummy variable if he/she belongs to the corresponding category, and 0 otherwise. As the dummy variables for a covariate are linearly dependent, one dummy variable is left out for each categorical covariate. The corresponding category is the so-called *reference category*. We took the *first* category of each covariate as the reference category.

The general procedure for collapsing categories is described in section 2.5.2. Special (deviant) cases of collapsing are mentioned below.

Age at admission (in years): *0, 1-4, 5-9, 10-14, …, 90-94, 95+*.

Sex of the patient: *male, female.*
If Sex is unknown, "female" was imputed; this happened only once.

SES (socio-economic status) of the postal area of patient's address: *lowest, below average, average, above average, highest, unknown.*

The SES variable was added to the LBZ/LMR dataset on the basis of the postal code of the patient's residence. SES was derived from the Netherlands Institute for Social Research (SCP)[3], which had collected SES data and performed principal component analyses on variables concerning Income, Employment and Education level. Each four-letter postal area was thus assigned a component score. Population-weighted quintiles were calculated from these scores, resulting in the six SES categories mentioned above. Patients for whom the postal area does not exist in the dataset of the SCP (category "unknown"), were added to the category "average" if

[3] see http://www.scp.nl/content.jsp? objectid=default:20133

collapsing was necessary. For 2011-2013, admissions followed the SES classification of 2010, whereas admissions of 2014 followed the SES classification of 2014.

Severity of main diagnosis groups: *[0-0.01), [0.01-0.02), [0.02-0.05), [0.05-0.1), [0.1-0.2), [0.2-0.3), [0.3-0.4), [0.4-1], Other*.

This is a categorisation into mortality rates. Each ICD9-CM main diagnosis code is classified in one of these groups, as explained below.

A separate model was estimated for each CCS diagnosis group. Most groups have many sub-diagnoses (individual ICD9-CM codes), which may differ in seriousness (mortality risk). To classify the severity of the sub-diagnosis, we used the method suggested by Van den Bosch et al. (2011), who suggested categorising the ICD9-CM codes into mortality rate categories. To this end, we computed inpatient mortality rates for all ICD9-CM sub-diagnoses for the period 2005-2011 and chose the following boundaries for the mortality rate intervals: 0, .01, .02, .05, .1, .2, .3, .4 and 1. ('0' means 0% mortality; '1' means 100% mortality). These boundaries are used for all CCS diagnosis groups. The higher severity categories only occur for a few diagnosis groups.

ICD9-CM codes that are used by less than four hospitals and/or have less than 20 admissions receive a severity of "other". The category "other" contains diagnoses for which it is not possible to accurately determine the severity. If this category "other" needs to be collapsed however, it does not have a natural nearby category. We decided to collapse "other" with the category with the highest frequency (i.e. the mode), if necessary. In the file with regression coefficients (see section 3.3) this will result in a coefficient for "other" equal to that of the category with which "other" is collapsed.

For the HSMR calculation of 2012-2014 a new file with severities has been calculated. These have been used for all years in the present HSMR calculation (2011-2014).

- One year has been added to the calculation of the severities. The severities used in previous years were based on the years 2005-2009. The year 2010 has been added, which should increase precision.
- The criterion for placing ICD9-CM codes in the category 'other' has changed. Previously, ICD9-CM codes that have admissions in fewer than five different hospitals were placed in the category "other", as suggested by Van den Bosch et al. (2011). To improve the calculated severities, his has been changed to less than four hospitals and/or having less than 20 admissions.
- Severities are now calculated for all ICD9-CM codes: also for codes outside the 50 CCS-groups used in the HSMR. Firstly, this was needed in our investigation into extending the 50 diagnosis groups (see section 5). Secondly, in order to determine the severity of diagnoses coded in ICD10, the ICD10 codes are first converted to ICD9-CM. This sometimes resulted in ICD9-CM codes that were not included in the original set of ICD9-CM codes for which the severity was calculated, resulting in a severity of 'other'. By calculating severities for all ICD9-CM codes this can be avoided.

Because of these changes the overall number of admissions for which a severity other than 'other' is assigned has increased. The impact on the resulting HSMRs of the present 50 CCS groups is minimal however.

The individual ICD9-CM codes with the corresponding severity category are available in a separate file published together with this report.

Urgency of the admission: elective, acute.
The definition of an acute admission is: an admission that cannot be postponed as immediate treatment or aid within 24 hours is necessary. Within 24 hours means 24 hours from the moment the specialist decides an acute admission is necessary.

Table A1.1. Comorbidity groups of Charlson index and the corresponding ICD9-CM codes

No.	Comorbidity groups	ICD9-CM codes	ICD10 codes
1	Acute myocardial infarction	410, 412	I21, I22, I252
2	Congestive heart failure	428	I50, I110, I130, I132, I255, I420, I425-I429, I43, P290
3	Peripheral vascular disease	441, 4439, 7854, V434	I70, I71, I731, I738, I739, I771, I790, I792, K551, K558, K559, Z958, Z959, R02
4	Cerebrovascular disease	430-438	G450-G452, G454, G458, G459, G46, I60-I69
5	Dementia	290	F00-F03, F051, G30, G311
6	Pulmonary disease	490-496, 500-505	J40-J47, J60-J67
7	Connective tissue disorder	7100, 7101, 7104, 7140-7142, 71481, 5171, 725	M05, M060, M063, M069, M32, M332, M34, M353
8	Peptic ulcer	531-534	K25-K28
9	Liver disease	5712, 5714-5716	B18, K700-K703, K709, K713-K715, K717, K73, K74, K760, K762-K764, K768, K769, Z944
10	Diabetes	2500-2503, 2507	E109, E119, E129, E139, E149
11	Diabetes complications	2504-2506	E100-E108, E110-E118, E120-E128, E130-E138, E140-E148
12	Hemiplegia or paraplegia	342, 3441	G041, G114, G801, G802, G81, G82, G830-G834, G838, G839
13	Renal disease	582, 5830-5832, 5834, 5836, 5837, 585, 586, 588	I120, I131, N01, N03, N052-N057, N18, N19, N25, Z490-Z492, Z940, Z992
14	Cancer	14-16, 18, 170-172, 174-176, 179, 190-194, 1950-1955, 1958, 200-208	C00-C26, C30-C34, C37-C41, C43, C45-C58, C60-C76, C81-C85, C88, C90-C97
15	HIV	042-044	B20-B24
16	Metastatic cancer	196-198, 1990, 1991	C77-C80
17	Severe liver disease	5722-5724, 5728	I850, I859, I864, I982, K704, K711, K721, K729, K765, K766, K767

Comorbidity_1 – Comorbidity_17. All these 17 covariates are dummy variables, having categories: *0* (*no*) and *1* (*yes*).

The 17 comorbidity groups are listed in Table A1.1, with their corresponding ICD9-CM and ICD10 codes. These are the same comorbidity groups as in the Charlson index. However, separate dummy variable are used for each of the 17 comorbidity groups.
Up to 2012 the ICD9-CM definitions of the Charlson comorbidities are used, and from 2013 onwards the ICD10 definitions are used. For the data for 2012 and earlier, the minority of diagnoses registered in ICD10 were first converted to ICD9-CM and then classified in the ICD9-CM Charlson comorbidity groups. For 2012, however, it was decided not to include ICD10 code Z95.5 in comorbidity group 3 (peripheral vascular disease), as after converting to ICD9-CM this code would end up in this comorbidity group, while this (coronary) diagnosis does not belong there. For the few hospitals that still registered in ICD9-CM in 2013 the diagnoses are converted to ICD10 and then classified according to the ICD10 definitions of the Charlson comorbidities.

All secondary diagnoses registered in the LBZ/LMR and belonging to the 17 comorbidity groups are used, but if a secondary diagnosis is identical to the main diagnosis, it is not considered a comorbidity. Secondary diagnoses registered as a complication arising during the hospital stay are not counted as a comorbidity either.

In conformity with the collapsing procedure for other covariates, comorbidity groups registered in fewer than 50 admissions or that have no deaths are left out, as the two categories of the dummy variable are then collapsed. An exception was made for Comorbidity_17 (Severe liver disease) and Comorbidity_11 (Diabetes complications). Instead of leaving out these covariates in the case of fewer than 50 admissions or no deaths, they are first added to the less severe analogues Comorbidity_9 (Liver diseases) and Comorbidity_10 (Diabetes), respectively. If the combined comorbidities still have fewer than 50 admissions or no deaths, then these are dropped after all.

Source of admission: *home, nursing home or other institution, hospital.*
This variable indicates the patient's location before admission.

Year of discharge: *2011, 2012, 2013. 2014*.
Inclusion of the year guarantees the number of observed and expected (predicted) deaths to be equal for that year. As a result the yearly (H)SMRs have an average of 100 when weighting the hospitals proportional to their expected mortality.

Month of admission: *January/February, …, November/December*.
The months of admission are combined into 2-month periods.

Appendix 2. Exclusion criteria for the calculation of HSMRs

Although all hospitals mentioned in section 2.1.1 are included in the model, HSMR outcome data were not produced for all hospitals. HSMRs were only calculated for hospitals that met the criteria for LBZ/LMR participation, data quality and case mix. In addition to this, only HSMRs were calculated for hospitals that had authorised CBS to supply their HSMR figures to DHD. Criteria used for excluding a hospital from calculating HSMRs were:

No inpatient admissions

0. Hospitals treating only day cases or outpatients are excluded, as calculation of the HSMR is not relevant for them. In fact, these hospitals do not belong to the HSMR population. Therefore, a code "0" was assigned to this criterion.

Insufficient participation in the LBZ/LMR

1. From 2014 hospitals are required to register all inpatient admissions. From 2011 up until 2013 hospitals were excluded when they had fewer than six completely registered months in a year (for inpatient admissions).

Data quality

Hospitals are excluded if*:*

2. ≥2% of inpatient admissions have a vague diagnosis code (ICD9-CM codes 799.8 and 799.9, and from 2013 onwards ICD10 code R69).
3. ≤30% of inpatient admissions are coded as acute.
4. ≤0.5 secondary diagnoses are registered per inpatient admission, on average per hospital.[4]

Case mix

Hospitals are excluded if:

5. Observed mortality is less than 60 in all registered inpatient admissions (criterion from 2013 onwards). Up to 2012 the criterion used was an expected mortality of 50 or less in the 50 CCS groups, i.e. $E_{dk} \leq 50$.
6. ≤70% of inpatient hospital deaths are within the 50 CCS diagnosis groups considered.

In addition to the above-mentioned, criteria, hospitals are also excluded if they had not authorised CBS to supply their HSMR figures.

Table A2.1 gives a summary of the hospitals by the different criteria for exclusion for 2014, and Table A2.2 for 2012-2014. (H)SMRs for 2012-2014 are only calculated if hospitals fulfil the criteria in 2014 and in 2012, 2013 and the three-year period as a whole, and responded in all three years. From Table A2.1 it can be concluded that 82 hospitals met (almost) all criteria in 2014 and had granted authorisation. For the period 2012-2014 this is the case for 71 hospitals (see Table A2.2). So HSMR 2014 figures were produced for 82 hospitals, and HSMR 2012-2014 figures for 71 hospitals.

[4] For this criterion, all secondary diagnoses are considered, even if they do not belong to the 17 comorbidity groups used as covariates. If identical secondary diagnoses (identical ICD9-CM codes) are registered within one admission, only one is counted. If a secondary diagnosis is identical to the main diagnosis of the admission, it is not counted as a secondary diagnosis.

Table A2.1. Number of hospitals according to exclusion criteria, 2014

Criterion	Authorization	No authorization	Total hospitals
No/partial participation LBZ	5	0	5
of which no participation	*3*	*0*	*3*
of which partial response (<12 months complete registration)	*2*	*0*	*2*
≥2% vague diagnosis code	0	0	0
≤30% admissions coded as acute	0	0	0
≤ 0.5 secondary diagnoses per inpatient admission (average per hospital)	1	0	1
<60 mortality	1	0	1
≤ 70% hospital deaths within the 50 diagnosis groups considered	0	0	0
Does not fulfil >1 of above-mentioned exclusion criteria	0	1	1
Meet all criteria	82[a)]	0	82
Total hospitals	89	1	90

a) For two hospitals (H)SMRs were calculated even though the percentage of deaths in the 50 diagnosis groups was slightly lower than 70% in 2014. One of these hospitals also had slightly less acute admissions than the criterion of 30%. Both of these hospitals are grouped under "Meet all criteria".

Table A2.2. Number of hospitals according to exclusion criteria, 2012-2014

Criterion	Authorization	No authorization	Total hospitals
No/partial participation LBZ/LMR	10	0	10
of which no participation in one or more years	*8*	*0*	*8*
of which partial response (<6 months in 2012, 2013 or <12 months in 2014) in one or more years	*2*	*0*	*2*
≥2% vague diagnosis code	0	0	0
≤30% admissions coded as acute	1	0	1
≤ 0,5 secondary diagnoses per inpatient admission (average per hospital)	1	0	1
≤50 expected mortality / <60 mortality	1	0	1
≤ 70% hospital deaths within the 50 diagnosis groups considered	1	0	1
Does not fulfil >1 of above-mentioned exclusion criteria	3	1	4
Meet all criteria	71[a)]	1	72
Total hospitals	88	2	90

a) For one hospital (H)SMRs were calculated even though it had <6 months of complete registration in the years 2012-2013. This hospital had a response of >90% of inpatient admissions, not selective with respect to mortality. For one hospital (H)SMRs were calculated even though the percentage of deaths in the 50 diagnosis groups was slightly lower than 70% in 2012-2014. These hospitals are grouped under "Meet all criteria".

Appendix 3. Results of the logistic regressions

Table A3.1. Statistical significance (95% confidence) of the covariates for the 50 logistic regressions (1=significant; 0=non-significant; "-"=variable dropped because of < 50 admissions or no deaths)

No. CCS group	Severity main diagnosis	Sex	Age	Urgency	Comorbidity_1	Comorbidity_2	Comorbidity_3	Comorbidity_4	Comorbidity_5	Comorbidity_6	Comorbidity_7	Comorbidity_8	Comorbidity_9	Comorbidity_10	Comorbidity_11	Comorbidity_12	Comorbidity_13	Comorbidity_14	Comorbidity_15	Comorbidity_16	Comorbidity_17	SES	Month admission	Year discharge	Source admission
2	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1	-	1	1	0	1	1	1
12	0	0	0	1	0	1	0	1	0	0	0	-	1	0	-	-	1	0	-	1	-	0	0	0	1
13	0	0	1	1	1	1	1	1	-	1	0	0	1	0	0	-	1	0	-	1	-	0	0	0	0
14	1	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	-	1	-	0	0	1	1
15	-	1	1	1	1	1	1	1	0	1	0	-	1	0	0	-	1	0	-	1	-	0	0	1	1
17	0	0	1	1	0	1	0	1	0	0	0	-	1	1	0	-	1	0	-	1	-	1	0	1	0
19	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	1	-	1	1	0	0	1	1
24	1	0	0	1	0	1	0	0	0	0	0	-	1	0	-	-	1	0	-	1	-	0	0	1	1
29	1	-	1	1	0	1	0	1	0	1	0	-	-	0	0	-	1	0	-	1	-	0	0	1	0
32	1	0	1	1	1	1	0	1	0	0	0	-	1	0	0	-	1	1	-	1	-	0	0	1	0
38	1	0	1	1	1	1	0	1	-	1	0	1	1	0	0	1	1	1	0	1	-	1	0	1	1
39	1	0	1	1	1	1	0	1	1	0	0	-	1	0	0	-	1	1	-	0	-	0	0	1	1
42	1	0	1	1	1	1	1	1	0	1	1	1	1	0	1	0	1	1	-	1	1	0	0	1	1
44	1	0	1	1	0	1	0	1	1	1	0	-	1	0	-	0	1	0	-	1	-	0	0	0	1
50	1	1	1	1	1	1	1	1	0	0	0	-	1	0	0	0	1	1	-	0	-	0	0	1	0
55	1	1	1	0	0	1	1	0	1	1	0	-	0	0	0	0	0	1	-	1	1	0	0	1	1
59	1	0	1	1	0	1	0	0	1	1	0	0	0	0	0	0	1	0	-	1	1	0	0	1	1
85	1	1	1	1	0	1	0	1	0	1	-	-	1	0	0	0	1	1	-	1	-	0	0	1	0
96	1	0	1	1	1	1	1	1	1	1	0	-	1	0	1	0	1	1	-	0	-	1	0	1	1
100	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1	1	-	1	1	1	1	1	1
101	1	0	1	1	1	1	1	1	0	1	0	1	1	1	0	0	1	1	-	1	-	0	1	1	1
103	1	1	1	1	1	1	1	1	1	1	0	-	1	1	1	0	1	1	-	1	1	0	1	1	1

No. CCS group	Severity main diagnosis	Sex	Age	Urgency	Comorbidity_1	Comorbidity_2	Comorbidity_3	Comorbidity_4	Comorbidity_5	Comorbidity_6	Comorbidity_7	Comorbidity_8	Comorbidity_9	Comorbidity_10	Comorbidity_11	Comorbidity_12	Comorbidity_13	Comorbidity_14	Comorbidity_15	Comorbidity_16	Comorbidity_17	SES	Month admission	Year discharge	Source admission
106	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	-	1	1	1	1	1	1
107	1	1	1	1	1	0	1	1	1	1	0	-	1	1	1	-	1	1	-	1	-	0	1	1	1
108	-	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	-	1	1	0	1	1	1
109	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	-	1	1	0	1	1	1
114	1	1	1	1	1	1	1	1	1	1	0	0	1	1	0	0	1	1	-	1	1	0	1	1	1
115	1	1	1	1	0	1	1	1	1	1	0	-	1	0	1	1	1	0	-	1	-	0	1	1	0
116	1	0	1	1	1	1	1	1	1	1	0	-	1	0	1	0	1	1	-	1	-	0	0	1	1
117	1	0	1	1	1	1	1	1	0	1	1	-	1	0	0	0	1	1	-	1	-	0	1	1	1
122	1	1	1	0	1	1	1	1	1	0	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1
127	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	0	1	1	0	1	1	1
129	-	1	1	0	0	1	1	0	1	0	0	-	1	0	0	0	0	1	-	1	-	0	0	1	0
130	1	0	1	1	1	1	0	1	0	1	0	-	1	1	0	-	1	1	-	1	-	0	0	1	1
133	1	1	1	1	1	1	1	1	1	1	1	-	1	1	0	1	1	1	-	1	1	0	1	1	1
145	1	1	1	1	1	1	1	1	1	1	0	-	1	1	1	1	1	1	-	1	-	0	0	1	0
146	1	0	1	1	1	1	1	0	1	1	1	-	1	0	0	-	1	1	-	1	-	0	0	0	1
149	1	0	1	1	1	1	0	1	1	1	1	0	1	0	1	0	1	1	-	1	1	0	0	1	1
150	1	1	1	1	0	1	1	-	-	1	-	0	1	0	-	-	1	1	-	-	1	0	0	1	1
151	1	0	1	1	0	1	1	1	0	1	1	0	1	1	1	-	1	1	-	1	1	0	0	1	1
153	1	0	1	1	0	1	1	1	1	1	0	0	1	0	0	0	1	1	-	1	1	0	0	1	1
155	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	0	1	1	-	1	0	0	0	0	1
157	1	0	1	1	1	1	1	0	1	1	0	0	1	0	0	1	1	1	-	1	1	1	0	1	1
158	1	1	1	1	0	1	1	0	1	1	0	-	0	0	0	-	0	0	-	1	-	1	0	1	1
159	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	-	1	1	0	1	1	1
226	1	1	1	0	1	1	1	1	1	1	0	0	1	1	1	0	1	1	-	1	-	0	1	1	0
233	1	1	1	1	1	1	1	1	1	1	0	-	1	0	0	0	1	1	-	1	-	1	0	0	0
237	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	1	1
238	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1	1	-	1	1	1	0	1	1
249	-	1	1	0	1	1	1	0	-	0	-	1	1	0	-	-	1	1	-	1	1	0	0	1	0
Total	43	25	48	44	34	49	38	40	30	40	11	13	46	19	19	12	47	40	0	46	23	10	16	44	38

Table A3.2. A Wald chi-square statistics for the 50 logistic regressions

No. CCS group	Severity main diagnosis	Sex	Age	Urgency	Comorbidity_1	Comorbidity_2	Comorbidity_3	Comorbidity_4	Comorbidity_5	Comorbidity_6	Comorbidity_7	Comorbidity_8	Comorbidity_9	Comorbidity_10	Comorbidity_11	Comorbidity_12	Comorbidity_13	Comorbidity_14	Comorbidity_15	Comorbidity_16	Comorbidity_17	SES	Month admission	Year discharge	Source admission
2	876	60	902	0	33	157	51	16	18	29	5	11	46	8	0	3	57	109	-	117	49	7	18	37	26
12	0	0	14	277	1	19	3	6	0	0	0	-	12	3	-	-	9	0	-	102	-	8	10	6	10
13	0	0	24	258	6	13	9	9	-	9	2	0	9	0	1	-	20	3	-	106	-	4	4	6	1
14	18	8	332	624	43	92	23	5	2	24	0	16	80	1	1	3	81	11	-	208	-	10	3	81	20
15	-	7	109	307	11	35	11	16	1	5	0	-	16	3	0	-	19	1	-	52	-	3	4	23	6
17	2	1	58	276	0	41	3	17	0	3	0	-	8	12	2	-	31	0	-	69	-	14	9	31	5
19	60	12	99	3168	15	133	21	46	0	65	3	8	30	11	8	1	50	7	-	251	17	4	9	71	47
24	17	1	16	664	0	16	3	0	0	0	3	-	38	2	-	-	12	0	-	139	-	4	3	13	6
29	10	-	57	183	1	8	2	7	3	10	1	-	-	1	0	-	27	2	-	176	-	5	4	10	2
32	19	0	34	392	12	35	0	11	1	1	1	-	8	4	2	-	33	17	-	255	-	2	8	23	6
38	15	0	87	448	11	49	1	13	-	8	4	6	74	0	4	8	64	9	0	20	-	11	7	22	63
39	133	2	225	201	10	33	0	43	4	3	1	-	17	3	3	-	41	21	-	0	-	11	5	28	27
42	79	2	127	1649	12	125	18	40	0	28	4	10	31	2	7	0	117	5	-	350	35	7	7	106	33
44	28	2	55	73	1	38	0	10	4	12	3	-	8	1	-	1	9	1	-	8	-	4	5	2	7
50	75	5	129	46	15	77	40	9	2	2	1	-	7	0	3	0	58	7	-	0	-	4	4	27	2
55	471	11	293	2	1	64	5	2	4	18	0	-	1	2	2	3	0	8	-	30	6	4	8	13	6
59	164	0	62	60	2	77	3	3	5	8	1	0	0	0	0	0	11	3	-	32	7	3	7	28	12
85	412	5	90	8	2	12	0	6	0	32	-	-	5	0	1	2	8	11	-	24	-	3	3	10	3
96	92	0	174	101	21	169	27	22	5	34	1	-	28	1	6	0	75	9	-	2	-	18	6	23	23
100	1021	0	1431	39	6	584	55	76	40	64	1	2	28	11	30	4	86	63	-	23	26	20	21	34	38
101	141	1	436	85	8	405	30	48	0	21	2	7	41	10	3	0	100	36	-	21	-	4	11	15	71
103	100	7	201	29	6	238	4	72	29	27	2	-	24	5	5	0	30	21	-	56	6	4	12	39	56
106	489	10	527	88	3	236	9	45	31	69	0	7	8	9	7	6	51	15	-	41	38	16	19	24	53
107	576	6	279	179	19	1	19	7	9	82	1	-	19	19	9	-	24	16	-	5	-	3	13	74	67
108	-	16	1192	129	46	23	51	95	67	147	26	26	89	4	24	7	311	52	-	74	49	7	52	197	78

No. CCS group	Severity main diagnosis	Sex	Age	Urgency	Comorbidity_1	Comorbidity_2	Comorbidity_3	Comorbidity_4	Comorbidity_5	Comorbidity_6	Comorbidity_7	Comorbidity_8	Comorbidity_9	Comorbidity_10	Comorbidity_11	Comorbidity_12	Comorbidity_13	Comorbidity_14	Comorbidity_15	Comorbidity_16	Comorbidity_17	SES	Month admission	Year discharge	Source admission
109	8153	9	2119	77	104	562	25	65	55	101	0	2	46	17	4	67	73	118	-	109	6	6	25	184	20
114	1143	8	276	402	28	162	66	21	8	30	1	0	15	5	1	2	104	33	-	10	7	3	17	52	32
115	1371	33	553	376	3	36	17	27	12	25	0	-	36	1	13	8	31	2	-	12	-	8	14	18	1
116	132	1	144	300	22	77	12	31	17	19	3	-	17	2	5	3	45	8	-	11	-	5	10	11	7
117	288	2	124	102	17	88	40	5	3	7	4	-	54	0	0	0	35	12	-	10	-	4	14	21	8
122	61	32	2737	1	107	711	66	110	51	0	17	17	35	1	6	41	125	349	1	290	95	18	16	123	98
127	71	10	533	101	19	440	47	11	22	5	8	1	19	10	0	6	64	23	0	41	17	4	62	40	52
129	-	6	181	2	1	47	8	0	6	4	0	-	10	2	2	0	2	18	-	16	-	3	2	19	3
130	22	1	254	76	5	27	0	7	1	26	1	-	33	15	1	-	27	6	-	52	-	6	7	36	35
133	981	16	460	397	12	159	18	14	16	60	16	-	39	6	4	6	12	72	-	143	25	3	14	40	119
145	197	8	927	5	6	114	42	9	13	69	1	-	21	9	7	10	68	25	-	59	-	6	4	36	6
146	54	3	261	51	14	80	34	2	23	15	19	-	28	1	0	-	40	33	-	33	-	2	7	1	8
149	176	1	461	25	9	113	3	18	8	54	4	2	28	3	5	4	71	7	-	50	20	4	7	28	6
150	24	5	18	89	1	34	6	-	-	4	-	2	16	2	-	-	53	8	-	-	75	4	4	10	14
151	484	0	90	75	2	76	11	7	1	10	18	1	8	5	6	-	80	25	-	33	43	4	10	29	75
153	329	3	224	9	2	174	14	45	11	14	0	0	95	1	0	0	54	15	-	129	10	6	2	29	12
155	1368	3	287	22	0	40	20	4	0	1	2	13	7	1	0	2	48	12	-	54	4	6	1	7	11
157	11	0	410	48	11	155	9	2	5	33	0	3	9	0	0	8	8	12	-	60	56	12	10	31	20
158	5	7	216	194	4	55	15	4	6	7	0	-	3	1	0	-	2	2	-	18	-	16	2	11	26
159	48	2	581	17	7	208	24	12	13	14	4	8	13	17	4	7	92	7	-	53	9	8	17	49	19
226	13	151	631	0	85	536	26	69	24	107	2	2	130	6	12	2	190	20	-	28	-	1	16	105	1
233	1903	35	439	5	28	66	16	42	6	6	1	-	18	2	0	0	8	8	-	18	-	12	4	2	5
237	330	4	316	158	31	203	73	27	5	26	14	12	58	5	5	8	48	38	3	9	33	5	3	22	95
238	464	0	488	17	18	126	45	15	19	35	3	3	29	35	13	3	47	29	-	59	11	14	6	82	150
249	-	4	158	0	12	20	5	3	-	3	-	10	9	1	-	-	8	7	-	11	5	8	11	12	2
Total	22423	501	19839	11834	832	6987	1031	1178	552	1373	178	169	1403	259	206	216	2656	1316	4	3468	645	348	536	1943	1493

Table A3.2. B Degrees of freedom for the Wald chi-square statistics for the 50 logistic regressions.

No. CCS group	Severity main diagnosis	Sex	Age	Urgency	Comorbidity_1	Comorbidity_2	Comorbidity_3	Comorbidity_4	Comorbidity_5	Comorbidity_6	Comorbidity_7	Comorbidity_8	Comorbidity_9	Comorbidity_10	Comorbidity_11	Comorbidity_12	Comorbidity_13	Comorbidity_14	Comorbidity_15	Comorbidity_16	Comorbidity_17	SES	Month admission	Year discharge	Source admission
2	4	1	20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
12	1	1	11	1	1	1	1	1	1	1	1	-	1	1	-	-	1	1	-	1	-	4	5	3	2
13	1	1	13	1	1	1	1	1	-	1	1	1	1	1	1	-	1	1	-	1	-	4	5	3	2
14	3	1	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	5	5	3	2
15	-	1	12	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	4	5	3	2
17	2	1	12	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	4	5	3	2
19	2	1	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
24	2	1	13	1	1	1	1	1	1	1	1	-	1	1	-	-	1	1	-	1	-	4	5	3	2
29	1	-	9	1	1	1	1	1	1	1	1	-	-	1	1	-	1	1	-	1	-	4	5	3	2
32	2	1	13	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	5	5	3	2
38	4	1	15	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	-	5	5	3	2
39	5	1	19	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	5	5	3	2
42	4	1	19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
44	4	1	15	1	1	1	1	1	1	1	1	-	1	1	-	1	1	1	-	1	-	4	5	3	2
50	4	1	15	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	5	5	3	2
55	3	1	16	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	1	5	5	3	2
59	2	1	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	4	5	3	2
85	1	1	19	1	1	1	1	1	1	1	-	-	1	1	1	1	1	1	-	1	-	4	5	3	2
96	5	1	14	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	5	5	3	2
100	2	1	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
101	3	1	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	5	5	3	2
103	3	1	17	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	1	5	5	3	2
106	2	1	20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
107	1	1	16	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	4	5	3	2
108	-	1	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2

No. CCS group	Severity main diagnosis	Sex	Age	Urgency	Comorbidity_1	Comorbidity_2	Comorbidity_3	Comorbidity_4	Comorbidity_5	Comorbidity_6	Comorbidity_7	Comorbidity_8	Comorbidity_9	Comorbidity_10	Comorbidity_11	Comorbidity_12	Comorbidity_13	Comorbidity_14	Comorbidity_15	Comorbidity_16	Comorbidity_17	SES	Month admission	Year discharge	Source admission
109	4	1	19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
114	4	1	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
115	5	1	13	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	5	5	3	2
116	3	1	13	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	4	5	3	2
117	4	1	18	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	5	5	3	2
122	5	1	20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	5	3	2
127	3	1	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	5	3	2
129	-	1	18	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	4	5	3	2
130	3	1	17	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	5	5	3	2
133	5	1	20	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	1	5	5	3	2
145	4	1	18	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	5	5	3	2
146	1	1	11	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	4	5	3	2
149	4	1	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	4	5	3	2
150	1	1	10	1	1	1	1	-	-	1	-	1	1	1	-	-	1	1	-	-	1	4	5	3	2
151	5	1	17	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	-	1	1	4	5	3	2
153	4	1	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
155	4	1	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	4	5	3	2
157	1	1	17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	4	5	3	2
158	1	1	14	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	4	5	3	2
159	3	1	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
226	1	1	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	5	5	3	2
233	8	1	20	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	5	5	3	2
237	3	1	19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	5	3	2
238	6	1	17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
249	-	1	11	1	1	1	1	1	-	1	-	1	1	1	-	-	1	1	-	1	1	4	5	3	2
Total	143	49	765	50	50	50	50	49	46	50	47	26	49	50	45	35	50	50	4	49	24	230	250	150	100

* The numbers of the comorbidity groups in the header of tables A3.1 and A3.2 are the following comorbidities:

Comorbidity_1 - Acute myocardial infarction
Comorbidity_2 - Congestive heart failure
Comorbidity_3 - Peripheral vascular disease
Comorbidity_4 - Cerebral vascular accident
Comorbidity_5 - Dementia
Comorbidity_6 - Pulmonary disease
Comorbidity_7 - Connective tissue disorder
Comorbidity_8 - Peptic ulcer
Comorbidity_9 - Liver disease / Severe liver disease
Comorbidity_10 - Diabetes / Diabetes complications
Comorbidity_11 - Diabetes complications
Comorbidity_12 - Paraplegia
Comorbidity_13 - Renal disease
Comorbidity_14 - Cancer
Comorbidity_15 - HIV
Comorbidity_16 - Metastatic cancer
Comorbidity_17 - Severe liver disease

Appendix 4 Summaries of individual models

In “Coefficients HSMR 2014.xls” the coefficients and standard errors for the logistic regressions of inpatient mortality are presented for each CCS diagnosis group, as explained in section 3.3.

Explanation of symbols

Empty cell	Figure not applicable
.	Figure is unknown, insufficiently reliable or confidential
*	Provisional figure
**	Revised provisional figure
2014–2015	2014 to 2015 inclusive
2014/2015	Average for 2014 to 2015 inclusive
2014/'15	Crop year, financial year, school year, etc., beginning in 2014 and ending in 2015
2012/'13–2014/'15	Crop year, financial year, etc., 2012/'13 to 2014/'15 inclusive

Due to rounding, some totals may not correspond to the sum of the separate figures.

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