HSMR 2011: Methodological report

Abby Israëls, Jan van der Laan, Janneke van den Akker-Ploemacher and Agnes de Bruin

Publication date Statistics Netherlands website: 1-11-2012

Statistics Netherlands

The Hague/Heerlen

Explanation of symbols

.	data not available
*	provisional figure
**	revised provisional figure (but not definite)
x	publication prohibited (confidential figure)
–	nil
–	(between two figures) inclusive
0 (0.0)	less than half of unit concerned
empty cell	not applicable
2011–2012	2011 to 2012 inclusive
2011/2012	average for 2011 up to and including 2012
2011/'12	crop year, financial year, school year etc. beginning in 2011 and ending in 2012
2009/'10–2011/'12	crop year, financial year, etc. 2009/'10 to 2011/'12 inclusive

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

Publisher
Statistics Netherlands
Henri Faasdreef 312
2492 JP The Hague

Prepress
Statistics Netherlands
Grafimedia

Cover
Teldesign, Rotterdam

Information
Telephone +31 88 570 70 70
Telefax +31 70 337 59 94
Via contact form:
www.cbs.nl/information

Where to order
E-mail: verkoop@cbs.nl
Telefax +31 45 570 62 68

Internet
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1. Introduction

Statistics Netherlands (CBS) has calculated the Hospital Standardised Mortality Ratios (HSMRs) for Dutch hospitals for the period 2009-2011. The HSMRs are ratios of observed and expected number of deaths and aim to present comparable hospital mortality figures. This report describes the methods that were used. They are nearly identical to those used for the period 2008-2010 as described in CBS (2011), so the results of the models of the two periods can easily be compared. For clarity, this report follows the same structure and contents as of the previous report. Differences with CBS (2011) regarding the model are mentioned in chapter 2. Practically, these differences hardly influenced the HSMR results. In chapter 3 some additional research on the HSMR model is described

In this introductory chapter, section 1.1 deals with the definition of the HSMR and the diagnosis specific SMR, section 1.2 with the purpose of the HSMR and section 1.3 with its history. Authorization was asked from the hospitals to deliver the HSMR figures (section 1.4). Section 1.5 gives an overview of the types of figures CBS has produced and section 1.6 presents 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. Finally, there are three 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.

1.1 What is the (H)SMR?

Hospital mortality can be measured as the ratio of the number of hospital deaths and 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 hospital. For this purpose, it is more appropriate to adjust (standardise) the mortality rates across hospitals as much as possible for differences in characteristics of the patients admitted to those hospitals ("casemix"). To this end, the *SMR* (Standardised Mortality Ratio) of a hospital *h* for diagnosis *d* is defined as

$$SMR_{dh} = 100 \text{ x } (\text{Observed mortality})_{dh} / (\text{Expected mortality})_{dh} .$$

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 admissions 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 based on a model based on data of 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 it is an acute, unplanned admission or a planned admission. Characteristics of the hospital, such as the number of doctors per bed, are generally not incorporated into the model, since these can be related to the quality of care in the hospitals, which is meant to be the 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 is equal to 100, when weighting each hospital with its (relative) expected mortality.

Not all diagnoses are inspected, but only 50 "diagnosis groups *d*" that cover about 80% of the entire hospital mortality. Also day admissions are excluded.

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

$$HSMR_h = 100 \text{ x (Observed mortality)}_h \text{ / (Expected mortality)}_h ,$$

in which both the numerator and denominator are sums across all admissions for all considered diagnoses. The HSMR has thus a weighted average of 100 as well.

HSMRs may also be different from 100 only by chance. Therefore, confidence intervals of the SMRs and HSMRs are calculated, so that hospitals can see whether they have a (statistically) significantly high (low) adjusted mortality rate as compared with the average of 100.

1.2 Purpose of the HSMR

In the Netherlands, like all other western countries, there is a great interest in measuring the quality of health care. Hospitals can be assessed on various quality indicators, such as the number of medical personnel per bed or the presence of certain facilities. These indicators, however, do not measure the outcomes of the 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, e.g. age, gender and comorbidity, of the patients. Unfortunately, recovery is hard to measure and mostly takes place after patients are discharged from the hospital. Hospital mortality is a much more limited quality indicator, but well measurable. 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 would perfectly adjust for everything that cannot be influenced by the hospital, a value above 100 would always point to inferior care quality, and one could consider the difference between numerator and denominator as an estimate of "avoidable mortality"[1]. However, a perfect instrument for

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

measuring the quality of health care is impossible. A significantly high (H)SMR will at most be an indication of possible shortcomings in hospital care. But the high value may also be due to coding errors in the data or to the lack of essential covariates in the model, which are 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 the mortality probabilities was improved by incorporating additional covariates into the model. Analogous models were adopted by some other countries.

In 2005 Jarman started to calculate the (H)SMR for the Netherlands. Later on, the (H)SMRs for the hospitals in the Netherlands were calculated by Kiwa Prismant, in collaboration with Jarman and his colleagues of the 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 is 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), as it uses this data source for a number of health statistics (see www.statline.nl).

The starting point for CBS was the HSMR methods previously used by Kiwa Prismant. Advancing insight caused CBS to introduce some changes in the model for the HSMR 2008-2010 (for an overview of the changes, see CBS, 2011). This was done in close collaboration with, and largely based on the extensive research of the Dutch scientific HSMR Expert group set up by the hospital branch organizations. The model of the HSMR 2009-2011 described in this report, is nearly identical to that of 2008-2010.

1.4 Privacy

According to the Statistics Netherlands Act, CBS is obliged to keep all data from 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 a written permission from all hospitals to deliver their hospital specific (H)SMR figures to DHD. Last year the hospitals were asked for such an authorization for a five year period in a joint letter with DHD. This year, a request for authorization was only sent to the hospitals that had not authorized CBS the year before and that participated in the LMR 2011. CBS only supplies (H)SMR outcome reports to DHD of hospitals that have given authorization to do so. DHD in turn sends each hospital its individual outcome report. In the authorization letter to

the hospitals it was also made clear that CBS will not publish data about identifiable hospitals, but that the hospital branch organisations governing DHD (i.e. NVZ – *Nederlandse Vereniging van Ziekenhuizen*, and NFU – *Nederlandse Federatie van Universitair Medische Centra*) could decide to publish the individual hospital data, in consultation with the hospitals.

1.5 Output by CBS

CBS estimated the models for the expected mortality per diagnosis for 2009-2011. It calculated the HSMRs and SMRs for all hospitals that (1) had authorized CBS, (2) had registered all or a sufficient part of its admissions in the LMR in the relevant period and (3) had passed the exclusion criteria for quality and comparability, which means that the hospital's LMR data were not too deviant in some respects (see Appendix 2).

CBS has produced the following output:

1. A hospital-specific report for each hospital, sent via DHD, containing the HSMR and the diagnosis specific SMR figures for 2009-2011 and the individual years. SMRs are also presented for different patient groups (by age, sex and urgency of the admission). The hospitals can see how they score as compared with the national average, overall, and per diagnosis and patient group. CBS only made reports for the hospitals that passed the exclusion criteria and signed the authorization letter.
2. Report on the methods used for calculating the HSMR for 2009-2011 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 quality of hospital care. Furthermore, the quality and limitations of the HSMR (and the SMR) instrument are debated. 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:

- There are large differences between hospitals in coding the covariates. This is especially true with respect to the coding of comorbidities.
- It is impossible to perfectly adjust for differences in casemix (the type of patients treated by a hospital) simply because patients are not randomized to hospitals. There are patient factors (related to mortality) that are not coded in the LMR and therefore cannot be included in the expected mortality model (denominator of the HSMR). So essential covariates are missing. Therefore, if the casemix between hospitals differs too much, standardisation cannot solve this problem completely.
- Hospitals differ not only in casemix, but also in the type of surgical procedures they are permitted to perform. Not all hospitals are e.g. authorized to perform risky interventions as open heart surgery. 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 can differ in their policies regarding admission and discharge, which can affect the in-hospital mortality. One hospital may discharge a patient earlier than another hospital because there are, for instance, external terminal care facilities in the neighbourhood.

2. (H)SMR model

For each diagnosis group, we have to determine the expected hospital mortality, i.e. the denominator of the SMR. To this end we use logistic regression models with mortality as the target (dependent) variable and with various variables that are available in the LMR as covariates.

The regression models for the (H)SMR 2009-2011 and the (H)SMRs of the individual years use LMR data of the last four years, i.e. the period 2008-2011. The addition of 2008 increases the stability and accuracy of the estimates, while keeping the model up to date. This procedure is identical to the year before, when CBS had calculated (H)SMRs for 2008-2010 based on LMR data from 2007-2010.

Regarding the HSMR model, there are only a few differences with last year:

- conversion of ICD10 codes (International Classification of Diseases, 10th Revision) to ICD9-CM codes for some hospitals that started coding in ICD10 in 2011 (the majority of hospitals still coded in ICD9-CM in 2011);
- adaptation of the SES classification for 2011;
- small change in the handling of comorbidities;
- skipping the backward elimination procedure.

These differences will be explained in this chapter. Practically, these differences hardly influenced the HSMR results. For the sake of continuity it was decided to implement only minimal changes to the model this year. Moreover, for several possible changes in the methodology, more research is needed.

2.1 Target population and data file

2.1.1 Hospitals

"Hospital" is the primary observation unit. Hospitals report admission data (hospital stay data) in the LMR. However, not all hospitals participate in the LMR. In Table 1 the response numbers for 2011 are given.

Table 1. Participation of hospitals in the LMR 2011

Type of hospital	Total hospital population	LMR population	Total participating hospitals in LMR	Participating hospitals with partial response
General hospitals	84	84	77	13
University hospitals	8	8	8	1
Specialised hospitals	8[a)]	4[b)]	2	0
Total hospitals	100	96	87	14

a) Hospitals with a long-stay character are not included. Excluded are epilepsy clinics and long-stay centres for rehabilitation and asthma treatment. (Semi-)private clinics are also excluded; these mainly have outpatients and day cases.
b) Included are specialised hospitals for (1) lung diseases, (2) cancer, (3) rheumatic diseases, orthopaedics and rehabilitation, and (4) eye diseases.

In the HSMR model all short-stay hospitals with inpatient admissions participating in the LMR in 2008-2011 are included in principle. The target population thus includes all general, university and short-stay specialised hospitals with inpatient admissions. One of the 87 general hospitals participating in the LMR has day admissions only, and is therefore excluded from the model. Nine hospitals did not participate in the LMR in 2011. The admissions of these hospitals cannot be analysed. Another fourteen hospitals were partial non-respondents in 2011, in the sense that they only provided information on part of their inpatient admissions. Although imputations are made for these missing admissions in the LMR data file, these imputations are not appropriate for model building. However, the registered LMR admissions of the partial non-respondents are included in the HSMR model (with exceptions for three hospitals, see below). In total, the number of hospitals included in the HSMR model was 86 in 2011, 83 in 2010, 82 in 2009, and 81 in 2008.

We included only fully registered months for one partially non-responding hospital in 2011, and for two partially non-responding hospitals in 2010 in the model, as in the other months there were indications that fatal cases were registered completely and the non-fatal cases partially. The partially registered months of these hospitals were removed from the model as these would otherwise unjustly influence the estimates.

All the above mentioned hospitals were included in the model, but (H)SMRs were only calculated for hospitals that met the criteria for LMR participation, data quality and casemix (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 short stay Dutch hospitals during a certain period". The date of discharge, and not the day of admission, determines the year a record is assigned to. So the 2011 population of hospital stays comprises all inpatient admissions that ended in 2011. For the sake of convenience, we will sometimes name these hospital stays as "admissions", thus meaning the hospital stay instead of its very beginning.

Day admissions are excluded because these are in principle non-life-threatening cases with hardly any mortality.

Since there are many diagnoses with 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) cover 80.9% of the entire inpatient hospital mortality and 36.4% of the inpatient admissions in 2009-2011. Moreover, some registered admissions of two partially non-responding hospitals in 2010 and

one partially non-responding hospital in 2011 were excluded because of over-reporting fatal cases (see section 2.1.1).

Lastly, admissions of foreigners are excluded from the HSMR model. This is partly done in the context of possible future modifications of the model, when other data can be linked to the admissions of Dutch residents. The number of admissions of foreigners is relatively small (28,566 inpatient admissions in 2008-2011).

Altogether, we included 2,447,881 inpatient admissions, that are registered in the LMR within the 50 CCS diagnosis groups considered, in the model of 2008-2011.

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 have been performed.

The crude mortality rate for the population of 2,447,881 inpatient admissions mentioned in section 2.1 is 4.5%. 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 ICD9-CM codes registered in the 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 the clustering. This 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 the total hospital mortality. The 50 CCS groups are listed in Table 5 in section 3.2. The ICD9-CM codes of these 50 CCS groups are available in a separate file published together with this report.

Actually, these 50 CCS diagnosis groups were 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 years, CBS decided to use the same groups as Kiwa Prismant had, for reasons of continuity. So the model includes 50 separate logistic regressions, one for each CCS diagnosis group *d* that was selected.

In 2011 some hospitals started to register the main diagnoses according to the ICD10. It is envisaged that in 2013 all hospitals will code LMR diagnoses in ICD10.

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

Since in 2011 only a small minority coded in ICD10, we converted these ICD10 codes to their ICD9-CM equivalents[3].

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. For this one chooses those variables (available in the LMR) that are associated with patient in-hospital mortality. The more the covariates discriminate between hospitals, the bigger the effect on the (H)SMR.

Here follows a listing of the covariates used. More information about these covariates and their use in the analysis is found in Appendix 1.

The following 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 patient's address (6 categories). The SES classification per postal code is from The Netherlands Institute for Social Research (SCP). For 2011 an updated file of SCP has been 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 the admission (planned, not planned);
- Comorbidity_1 – Comorbidity_17, i.e. a separate dummy variable (indicator variable) for each of the 17 comorbidity groups that are part of the "Charlson index". The groups are listed in Table A1.1 in Appendix 1. Each dummy variable indicates whether the patient suffers from the specific comorbidity (e.g. diabetes), based on the secondary diagnoses registered in the LMR. The procedure with separate dummy variables instead of the Charlson index has been suggested by Lingsma and Pouw, who did research for the Dutch HSMR Expert group; see Appendix 1.
- Source of admission (4 categories: home, nursing home, general hospital, academic or top-clinical hospital), indicating the patient's location before the admission;
- Year of discharge (4 categories: 2008-2011);
- Month of admission (6 categories of two months).

In contrast to earlier years, no backward elimination method has been performed, in order to get more unbiased results. 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. Skipping the backward elimination has little influence on the HSMRs. Skipping the procedure resulted in a

[3] According to the conversion table 'ICD-10 naar ICD-9(CVZ80)' as published on www.icd-10.nl

mean absolute difference in the HSMRs of 2010 of less than 0.6 and an average increase in the standard errors of less than 0.02.

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* and 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

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

with X_{dhi} the scores of admission *i* of hospital *h* on the set of covariates, and $\hat{\beta}$ 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

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

It follows from the above formulae that:

$$HSMR_h = 100 \frac{\sum_d E_{dh} \frac{O_{dh}}{E_{dh}}}{E_h} = \sum_d \frac{E_{dh}}{E_h} SMR_{dh} \ . \qquad (2.6)$$

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 that the standard errors of the regression coefficients become too large. This collapsing is performed starting from 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 dealing with the chosen R-software, collapsing also took also place when there were no deaths in the category. All regression coefficients are presented in the file "Coefficients HSMR 2011.xls" published together with this report.

The following statistics are presented for evaluating the 50 models:

- *standard errors* for all regression coefficients (file "Coefficients HSMR 2011.xls");
- *statistical significance* of the covariates with significance level $\alpha = .05$, 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 situation, a logistic regression. Its maximum value of 1 points to perfect discriminating power and 0.5 points to a discriminating power not better than expected by chance, which will be the situation 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 for the statistical significance and the Wald statistics are presented in Tables 2 and 3 in section 3.1.

Besides these diagnostic measures for the regressions, we present the *average shift in HSMR* by inclusion vs. deletion of the covariate in/from the model (Table 4 in section 3.1). This average absolute difference in HSMR is defined as

$$\frac{1}{N} \sum_{h=1}^{N} | \ HSMR_h - HSMR_h^{-x_j} \ | \ , \qquad (3.1)$$

where $HSMR_h^{-x_j}$ is the HSMR that would be obtained by deletion of covariate x_j, and $N = 77$ the total number of hospitals that obtained a HSMR. for the year 2011.

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. This made us decide also to present how much the HSMRs change by deleting a covariate. Of course, a covariate that only has low Wald statistics has little impact on the (H)SMRs.

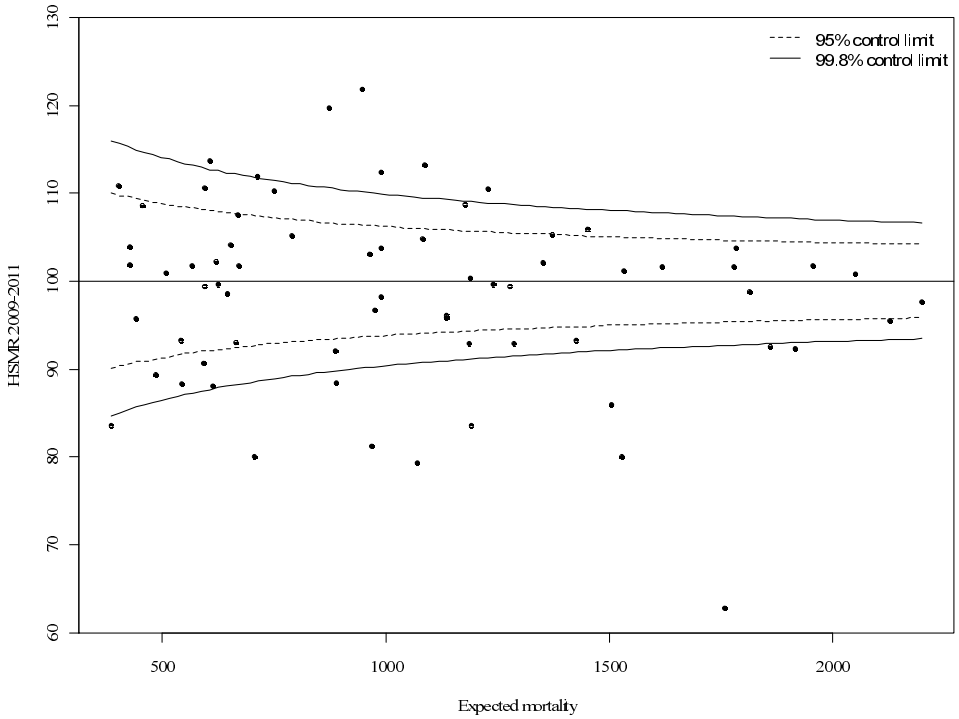
2.5.3 Confidence intervals and control limits

For each SMR and HSMR a 95% confidence interval is calculated, i.e. an upper and lower confidence limit. These limits are mentioned in the specific reports for the hospitals. A lower limit above 100 points to a statistically significant high (H)SMR, and an upper limit below 100 points to a statistically significant low (H)SMR. For the calculation of these confidence intervals, a Poisson distribution is assumed for the numerator of the (H)SMR, whereas 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 could compute exact confidence limits.

HSMRs can be presented in a funnel plot (see Figure 1). This is a plot of hospitals, where the vertical axis represents the HSMRs and the horizontal axis the expected mortalities. Points above the horizontal axis (HSMR=100) have a higher observed than expected mortality. As this might be a non-significant feature, due to 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 lie 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 casemix variables and/or suboptimal quality of care.

Figure 1 gives the funnel plot of the HSMRs 2009-2011. Exact control limits have been computed. As mentioned before, hospitals are excluded if their data did not pass the exclusion criteria or if they did not authorize CBS. As some of these hospitals are still represented in the expected mortality model, the (weighted) average HSMR of the displayed hospitals will not be exactly equal to 100. Actually, the weighted average HSMR of the displayed hospitals in 2009-2011 (n=67) is 97.7. For the year 2011 the average HSMR of the non-excluded hospitals (n=77) is 99.1. 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 2009-2011



The precision of the HSMR is much greater for a three-year period than for a single year, reflected by a smaller range between the control limits. The confidence intervals of the HSMR are smaller as well. This is why we presented HSMRs and corresponding funnel plots of three-year periods more often than one-year figures. Of course, drawbacks are that two progressive three-year figures (e.g. 2008-2010 and 2009-2011) are overlapping, and that the three-year figure is less up-to-date than the figure of the last year. Therefore we have also calculated the figures for the last available year (funnel plot of 2011 not presented). Observed mortality (numerator) and expected mortality (denominator) are then calculated for the 2011 admissions, whereas the expected mortality model of the HSMR still uses the 2008-2011 data. If a hospital has a significantly high HSMR in 2011, but not for 2009-2011, 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 2009-2011, but not in 2011, this does not necessarily mean that the situation has improved in 2011, as the one-year figures are less often significant because of the larger margins. In such cases one should not only take into account the significance, but also look at the HSMR levels over the years.

3. Model results and evaluation

In this chapter the model results are described and evaluated. Some summary measures are presented of the 50 logistic regressions, 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 2011.xls".

The computations were performed using the procedure "lrm" from the R-package "rms".

3.1 Impact of the covariates on mortality and HSMR

Table A3.1 of Appendix 3 shows for each CCS diagnosis group which covariates have a statistically significant (95% confidence) impact on in-hospital mortality: "1" points to (statistical) significance, and "0" to non-significance. The last line of Table A3.1 gives the numbers of significant results across the CCS groups for each covariate. These values are presented again in Table 2 below, as a summary, but ordered by the number of times a covariate is significant. Age, Year of discharge, Urgency of the admission and Severity of the main diagnosis are significant for the great majority of the 50 diagnosis groups. This is also true for the comorbidity groups 2, 13 and 16, i.e. for Congestive heart failure, Renal disease and Metastatic cancer. Comorbidity 15, HIV, was never significant. It was seldom registered as a comorbidity; most CCS groups had less than 50 admissions with HIV comorbidity.

Table 2. Statistical significance of the covariates for the 50 logistic regressions (summary)

Covariate	No. of significant results	Covariate	No. of significant results
Age	48	Comorbidity_9	26
Year of discharge	47	Sex	21
Comorbidity_16	47	SES	18
Comorbidity_2	47	Comorbidity_8	17
Comorbidity_13	46	Comorbidity_5	16
Urgency	44	Month of admission	15
Severity main diagnosis	42	Comorbidity_7	7
Comorbidity_4	41	Comorbidity_10	7
Comorbidity_14	41	Comorbidity_17	7
Comorbidity_6	40	Comorbidity_11	6
Comorbidity_1	40	Comorbidity_12	5
Source of admission	36	Comorbidity_15	0
Comorbidity_3	28		

Compared with the model results for the HSMR 2008-2010 (CBS, 2011), there is not much difference in the number of significances in general. An exception is SES,

whose number of significances has been doubled. This may be partly due to the use of the new SES classification for the records of 2011. But this change in postal area SES scores only has a small impact on the HSMRs: most of the HSMR 2011 scores changed less than 1 point. Also comorbidities are more often significant, as a result of an increase of registered comorbidities. Note that in the new HSMR model, we added 2011 and removed 2007.

Last year, for the HSMR 2008-2010, a backward elimination procedure was used and non-significant covariates were dropped from the model, with an exception of Year of discharge. This year, for the HSMR 2009-2011, the non-significant covariates are included in the model. Exclusion only happens for covariates that have all categories collapsed, as explained in section 2.5.2. These exclusions are denoted by hyphens in Tables A3.1 and A3.2.

The relative impact of the covariates is better judged by considering the Wald (chi-square) statistics for each covariate; see Table A3.2A of Appendix 3. The Wald statistic has been used for testing 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 having 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. Due to collapsing of categories if a category has less 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 when 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 line 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 3 below, these are presented again, as a summary, but now ordered by value. The sums of the degrees of freedom, the last line of Table A3.2B, are added to Table 3. It shows that Age has the highest explanatory power, with 26,194 as the sum of the Wald statistics. But Age has the most parameters by far. Severity of main diagnosis is also a covariate with a large impact on mortality and has fewer categories. Urgency of the admission is also an important variable. The explanatory power of Sex, Month of admission and SES is relatively small. This is also true for some comorbidity groups. Like in Table 2, 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 is equal to 20,760 with 648 df, but due to interference of comorbidities this only can give an indication of their combined

effect. Anyway, it can be concluded that several comorbidity groups also make an important contribution to the model.

Table 3. Wald chi-square statistics for the 50 logistic regressions

Covariate	Sum of Wald statistics	Sum of df	Covariate	Sum of Wald statistics	Sum of df
Age	26194	775	Sex	612	49
Severity main diagnosis	24294	143	Month of admission	549	250
Urgency	14253	50	Comorbidity_3	546	48
Comorbidity_2	6424	49	SES	396	219
Comorbidity_16	3440	49	Comorbidity_8	310	26
Comorbidity_13	3050	50	Comorbidity_5	289	41
Year of discharge	2072	150	Comorbidity_17	220	8
Source of admission	1747	137	Comorbidity_10	94	50
Comorbidity_14	1739	50	Comorbidity_7	87	39
Comorbidity_4	1421	49	Comorbidity_11	86	31
Comorbidity_1	996	50	Comorbidity_12	71	27
Comorbidity_9	993	29	Comorbidity_15	2	2
Comorbidity_6	992	50			

The main differences with the comparable Table 3 for the HSMR 2008-2010 in CBS (2011) are a consequence of the inclusion of non-significant covariates in the model this year, instead of using a backward elimination procedure. Covariates that are non-significant for many of the 50 regressions now have much larger sums of degrees of freedom (df). Month of admission, for instance has 6 categories and therefore 5 df for each of the 50 regressions. Since no categories had to be collapsed for this covariate, the sums of df is equal to 250, instead of 70 last year. Including the non-significant terms raises the sum of Wald statistics from 360 to 549. The sums of Wald statistics also rose for SES and several comorbidity groups, but the sums of the df increased as well. Moreover, SES is more often significant than it was for HSMR 2008-2010, as mentioned before. The impact of the comorbidity groups are also a result of the increase of registered comorbidities.

As mentioned before, Table 3 only gives a summary of Table A3.2. The effect of a covariate on mortality can be very different for different CCS groups.

Table 4 shows the impact of each covariate on the HSMR 2011, as measured by formula (3.1) for the 77 hospitals for which HSMRs are calculated. Whereas Age and Severity of the main diagnosis had the largest effect on mortality (for the years 2008-2011), their impact on *hospital* mortality is smaller, apparently due to relatively small differences in their distributions between the hospitals. Comorbidity discriminates much more between hospitals. This will be a result of differences in casemix, but possibly also of differences in coding practice. Notice that we consider the comorbidities here as one group. Deleting Sex has hardly any impact on the

HSMRs. Compared to Sex, SES has a quite reasonable impact on the HSMR 2011. This is because hospitals differ more in the SES categories of the postal areas in their vicinity than in the sex distribution of their patients. Although some covariates do not have much impact on the HSMRs it is still good to keep these in the model, because of their impact on mortality and because the distributions of the covariates between hospitals may change in future.

Table 4. Average shift in HSMR 2011 by inclusion vs. deletion of the covariate

Covariate	Average shift in HSMR	Covariate	Average shift in HSMR
Comorbidity [a)]	8.25	SES	1.05
Age	5.18	Source of admission	0.60
Urgency	3.17	Month of admission	0.40
Severity main diagnosis	2.50	Sex	0.16

a) The comorbidities have all been deleted as one group and not separately.

3.2 Model evaluation for the 50 regression analyses

Table 5 gives the number of admissions and deaths, and the C-statistics for the 50 CCS diagnosis groups. The meaning of the C-statistic is explained in section 2.5.2. The C-statistics do not differ much from the figures from last year in CBS (2011). Only "Cancer of esophagus" differs more than .02. On average, the values have become a little bit higher as the backward elimination was skipped.

Most of the values of the C-statistic lie between 0.7 and 0.9. The highest values are found for the CCS groups "Intracranial injury" (C=.93), "Cancer of breast" (C=.93), "Biliary tract disease" (C=.91), "Peripheral and visceral atherosclerosis" (C=.91) and "Other gastrointestinal disorders" (C=.91). For these five CCS groups the covariates strongly reduce the uncertainty in predicting patient's mortality. The lowest values are found for "Congestive heart failure; nonhypertensive" (C=.66), "Aspiration pneumonitis; food/vomitus" (C=.70), "Liver disease; alcohol-related" (C=.71) and "Chronic obstructive pulmonary disease and bronchiectas" (C=.71).

Table 5. 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)	17,263	4404	0.77
12	Cancer of esophagus	10,755	685	0.76
13	Cancer of stomach	14,669	731	0.79
14	Cancer of colon	40,302	1998	0.80
15	Cancer of rectum and anus	21,020	693	0.81
17	Cancer of pancreas	10,903	970	0.72
19	Cancer of bronchus; lung	74,060	5600	0.83
24	Cancer of breast	56,380	561	0.93
29	Cancer of prostate	23,382	580	0.89

CCS-group no.	Description CCS diagnosis group	Number of admissions	Number of deaths	C-statistic
32	Cancer of bladder	42,215	583	0.90
38	Non-Hodgkins lymphoma	19,983	982	0.82
39	Leukaemias	19,468	1154	0.84
42	Secondary malignancies	69,995	4941	0.78
44	Neoplasms of unspecified nature or uncertain behaviour	20,139	461	0.82
50	Diabetes mellitus with complications	32,306	626	0.86
55	Fluid and electrolyte disorders	27,096	1112	0.83
59	Deficiency and other anaemia	46,977	565	0.79
85	Coma; stupor; and brain damage	4,155	617	0.82
96	Heart valve disorders	34,756	1287	0.79
100	Acute myocardial infarction	90,904	5421	0.77
101	Coronary atherosclerosis and other heart disease	220,879	1738	0.80
103	Pulmonary heart disease	27,389	1194	0.79
106	Cardiac dysrhythmias	195,188	1586	0.86
107	Cardiac arrest and ventricular fibrillation	8,680	3853	0.77
108	Congestive heart failure; nonhypertensive	101,113	10611	0.66
109	Acute cerebrovascular disease	95,992	12895	0.77
114	Peripheral and visceral atherosclerosis	40,127	1825	0.91
115	Aortic; peripheral; and visceral artery aneurysms	26,700	2826	0.89
116	Aortic and peripheral arterial embolism or thrombosis	29,136	700	0.89
117	Other circulatory disease	22,493	527	0.86
122	Pneumonia (except that caused by tuberculosis or sexually transmitted diseases)	124,125	10602	0.78
127	Chronic obstructive pulmonary disease and bronchiectas	77,942	3617	0.71
129	Aspiration pneumonitis; food/vomitus	4,891	1264	0.70
130	Pleurisy; pneumothorax; pulmonary collapse	23,023	875	0.84
133	Other lower respiratory disease	103,873	4062	0.86
145	Intestinal obstruction without hernia	32,291	1878	0.84
146	Diverticulosis and diverticulitis	34,180	609	0.87
149	Biliary tract disease	124,818	756	0.91
150	Liver disease; alcohol-related	5,203	667	0.71
151	Other liver diseases	16,738	1126	0.81
153	Gastrointestinal haemorrhage	33,881	1289	0.80
155	Other gastrointestinal disorders	49,212	773	0.91
157	Acute and unspecified renal failure	10,919	1033	0.76
158	Chronic renal failure	18,333	694	0.86
159	Urinary tract infections	65,857	1563	0.83
226	Fracture of neck of femur (hip)	66,823	2826	0.79
233	Intracranial injury	59,525	1630	0.93
237	Complication of device; implant or graft	77,552	951	0.86
238	Complications of surgical procedures or medical care	71,295	1170	0.87
249	Shock	2,975	1453	0.74

3.3 Regression coefficients

The file "coefficients HSMR 2011.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 from the vector $\hat{\beta}_d$ from 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 clarity, the reference categories are given in the first line of the corresponding covariates, and have zero coefficient for each regression by definition. In many cases categories are collapsed (see section 2.5.2). This results in equal coefficients for the collapsed categories.

4. Limitations of the HSMR

From the first publication of the HSMR in England on, there have been discussions about the quality of the HSMR as an instrument. Pro and con agree that the HSMR is not a unique, ideal measure, but at most a possible indicator for the quality of health care, next to other possible indicators. But even in considering the HSMR with a more limited purpose, i.e. standardising hospital mortality rates for unwanted side-effects, the interpretation of HSMRs has various problems. We mention some of these. 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 coding e.g. unplanned admissions, main diagnosis and comorbidity may depend on the physician and the coder. Lilford and Pronovost (2010) argue that when the quality of the source data is insufficient, the regression model should not adjust for such erroneously coded covariates. Our own investigation (report forthcoming) shows that comorbidities especially form a problem, as there is no uniformity in coding this covariate so far (see also the next chapter). Van den Bosch et al. (2010) refer extensively to the influence of coding errors. Exclusion criteria for outliers can address this problem in part but not completely.

- Some hospitals may have more seriously ill patients than other hospitals, on average, even when they have the same set of scores on the covariates. University hospitals may have more serious cases than other hospitals. It is questionable whether the model adjusts satisfactorily for this phenomenon. Some essential covariates that are related to mortality are then missing. This can be due to the fact that some of the desired covariates are not (yet) measured in the LMR. Some factors will be hard to measure at all. But there are also important missed variables that may be measured in future years by the hospitals, such as palliative care.

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

- Hospitals can differ in admission and discharge policy. For instance, one hospital may admit the same patient more frequently but for shorter stays than the other. Or it discharges a patient earlier than the other because there are

external terminal care facilities in the neighbourhood. Besides, hospitals may also allocate health care in a different way, paying more or less attention to less acute cases. Obviously, all these situations influence the outcome of the HSMR, as it influences 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 *mutual* comparison between (H)SMRs of two or more hospitals is more complicated. There is no complete adjustment for differences in casemix 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, one should still be careful with mutual comparison of HSMRs (Heijink et al., 2008).

5. Possibilities for the future

We implemented some improvements in the HSMR model last year, of which the most important were a different classification of the severity of main diagnosis and a different way of processing the comorbidities. These changes were largely based on ideas from the Dutch HSMR Expert group and Van den Bosch et al. (2010). This year only minor changes in the model were implemented. In CBS (2011) some further possible changes for future were described. In short:

- Introducing an indicator including post-discharge mortality, besides the in-hospital mortality, in order to tackle the problem of variety in the availability of terminal care outside the hospital (e.g. mortality up to 30 days post-discharge, such as used in the UK, see Campbell et al., 2011). Regular implementation of such an indicator in the Netherlands depends on full coverage of the registration in the LMR of an unique identifier which can be linked by CBS to date of death in the population register.
- Calculating HSMRs for more homogeneous groups of hospitals such as university hospitals and cardiac centres, or restricting the calculations to SMRs for (clusters of) main diagnosis groups or specialisms. Drastic specialisation of hospitals could make this advisable.
- Updating or extending the "top-50" diagnosis groups included in the HSMR.
- Linking the LMR with other databases available at CBS, which can give extra patient variables to adjust for, such as household income or ethnicity, and which enables calculating new covariates as the "number of previous hospital admissions". Just as for the post-discharge mortality, a unique personal identifier in the LMR dataset is required to enable such linkages for all hospital patients.

More research is necessary before introducing these and other possible changes into the HSMR-model.

A PhD-researcher of the University of Utrecht is presently investigating, in collaboration with CBS, how including post-discharge mortality affects the HSMR outcomes in the Netherlands. In the UK the so-called "SHMI", which includes 30-day mortality, has replaced the HSMR since 2011 (Campbell et al., 2011).

With respect to data quality, CBS (report forthcoming) studied the impact of differences in the registration of some covariates, such as the Charlson comorbidities, 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 HSMRs as the more comorbidities, the lower the HSMR and vice versa. The same problem holds for the variation in the average number of registered Charlson comorbidities over years within hospitals. Therefore, much more

consistency in coding practice is necessary. The preservation of the Charlson comorbidities in the HSMR model could be dependent thereof.

6. References

Campbell, M.J., R.M. Jacques, J. Fotheringham, T. Pearson, R. Maheswaran and J. Nicholl (2011). *An evaluation of the Summary Hospital Mortality Index, final report.* School of Health and Related Research, The University of Sheffield.

CBS (2011). *HSMR 2010, Methodological report*. Statistics Netherlands, The Hague/Heerlen. http://www.cbs.nl/NR/rdonlyres/34A3E505-1AB8-45BC-9CCE-7011A326B8C5/0/hmsr2010methodologicalreportv2.pdf

Heijink, R., X. Koolman, D. Pieter, A. van der Veen, B. Jarman and G. Westert (2008). Measuring and explaining mortality in Dutch hospitals; The Hospital Standardized Mortality Rate between 2003 and 2005. *BMC Health Services Research* 8:73.

Jarman, B., D. Pieter, A.A. van der Veen, R.B. Kool, P. Aylin, A. Bottle and G.P. Westert (2010). The hospital standardised mortality ratio: a powerful tool for Dutch hospitals to assess their quality of care? *Qual Saf Healthcare* 19, 9-13.

Jarman, B., S. Gault, B. Alves, A. Hider, S. Dolan, A. Cook, B. Hurwitz and L.I. Iezzoni (1999). Explaining differences in English hospital death rates using routinely collected data, *BMJ* 318, 1515-1519.

Lilford, R. and P. Pronovost (2010). Using hospital mortality rates to judge hospital performance: a bad idea that just won't go away. *BMJ* 340:c2016.

Prismant (2008). *De toepasbaarheid van de HSMR in het toezicht van de inspectie voor de gezondheidszorg*. Prismant, Utrecht.

Van den Bosch, W.F., J. Silberbusch, K.J. Roozendaal en C. Wagner (2010). Variatie in codering patiëntengegevens beïnvloedt gestandaardiseerd ziekenhuissterftecijfer. *Ned Tijdschr Geneeskd.* 154 (2), 1-9.

Van den Bosch, W.F., P. Spreeuwenberg en C. Wagner (2011). Gestandaardiseerd ziekenhuissterftecijfer (HSMR): correctie voor ernst hoofddiagnose kan beter. *Ned Tijdschr Geneeskd.* 155:A3299, 66-75.

Van Gestel, Y.R.B.M., V.E.P.P. Lemmens, H.F. Lingsma, I.H.J.T. de Hingh, H.J.T Rutten.and J.W.W Coebergh (2012). The hospital standardized mortality ratio fallacy; a narrative review. *Medical Care* 50 (8), 662-667.

Acknowledgement

The authors would like to thank the Dutch HSMR Expert Group for their research on the HSMR model, the results of which we gratefully used for the improvement of the model last year (CBS, 2011).

Appendix 1. Covariates: definitions and use in regression analyses

In this appendix detailed information is given on the definitions and categories of the covariates, and their use in the regression analyses.

In 2011 some hospitals started to register the main diagnoses according to the ICD10. It is envisaged that in 2013 all hospitals will have switched their coding from ICD9-CM to ICD10. Since in 2011 only a small minority coded in ICD10, we converted these ICD10 codes to their ICD9-CM equivalents and used the converted codes for the (H)SMR 2009-2011 and (H)SMR 2011. For the conversion of the ICD10 codes we used the conversion table 'ICD-10 naar ICD-9(CVZ80)' as published on www.icd-10.nl.

The ICD9-CM codes of the 50 CCS diagnosis groups, the severity category of each ICD9-CM code, and the SES classification of the postal codes used for the year 2011 are published in an auxiliary file to this report ('Classification of variables HSMR 2011.xls').

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" has been imputed; this happened only twice.

SES (Socio-Economic Status) of the postal area of patient's address: *lowest, below average, average, above average, highest, unknown.*

The SES variable has been added to the 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)[4], that had collected SES data in 2006 and 2010 and performed principal component analyses on variables that deal with Income, Employment and Education level. Each four-letter postal area thus obtained a component score. Out of these scores, population-weighted quintiles are calculated, 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"), are added to the

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

category “average” if collapsing was necessary. For the 2008-2011 dataset, the admissions in 2008-2010 followed the SES classification from 2006, whereas admissions in 2011 followed the SES classification from 2010.

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

A separate model has been 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). He suggested categorizing 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 2005-2010, the same period as used before for the HSMR 2008-2010, 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. The individual ICD9-CM codes with the corresponding severity category are available in a separate file published together with this report.

A limitation of this procedure is that partially the same dataset is used for calculating the mortality rates for the severity variable (2005-2010) and for the mortality target variable of the HSMR (2009-2011). This overlap will automatically wash out when HSMRs are calculated for later years. To diminish its effect on the SMRs, ICD9-CM codes that have admissions in less than five different hospitals were put in the category “others”, as suggested by Van den Bosch. It is actually a category of admissions with ICD9-CM codes for which the mortality rates are unreliable.

Just like for the other covariates, categories are collapsed with nearby categories if the number of admissions is smaller than 50 or when there are no deaths. The category “others”, however, does not have a natural nearby category. We decided to collapse “others” with the category having the highest frequency (i.e. the mode), if necessary.

Urgency of the admission: *planned, not planned (acute)*.

The definition of an acute admission is: an admission that was not planned (for that moment) and cannot be postponed since immediate aid (observation, examination or treatment) is necessary.

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 codes. These are the same comorbidity groups as used in the Charlson index. However, separate dummy variable are used for each of the 17 comorbidity groups, as advised by the Dutch HSMR Expert group.

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

No.	Comorbidity groups (Charlson variables)	ICD9-CM codes
1	Acute myocardial infarction	410, 412
2	Congestive heart failure	428
3	Peripheral vascular disease	441, 4439, 7854, V434
4	Cerebral vascular accident	430–438
5	Dementia	290
6	Pulmonary disease	490, 491, 492, 493, 494, 495, 496, 500, 501, 502, 503, 504, 505
7	Connective tissue disorder	7100, 7101, 7104, 7140, 7141, 7142, 71481, 5171, 725
8	Peptic ulcer	531, 532, 533, 534
9	Liver disease	5712, 5714, 5715, 5716
10	Diabetes	2500, 2501, 2502, 2503, 2507
11	Diabetes complications	2504, 2505, 2506
12	Paraplegia	342, 3441
13	Renal disease	582, 5830, 5831, 5832, 5836, 5837, 5834, 585, 586, 588
14	Cancer	14, 15, 16, 18, 170, 171, 172, 174, 175, 176, 179, 190, 191, 192, 193, 194, 1950, 1951, 1952, 1953, 1954, 1955, 1958, 200, 201, 202, 203, 204, 205, 206, 207, 208
15	HIV	042, 043, 044
16	Metastatic cancer	196, 197, 198, 1990, 1991
17	Severe liver disease	5722, 5723, 5724, 5728

All secondary diagnoses registered in the 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.

In conformity with the collapsing procedure for other covariates, comorbidity groups that are registered in less than 50 admissions or that have no deaths are left out, as the two categories of the dummy variable are then collapsed. An exception has been made for Comorbidity_17 (Severe liver disease) and Comorbidity_11 (Diabetes complications). Instead of leaving out these covariates in case of less 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 less than 50 admissions or no deaths, then these are dropped after all.

In the previous model for the HSMR 2008-2010, Comorbidities 17 and 11 were always added to Comorbidities_9 and 10, respectively, even if the separate comorbidities had 50 admissions or more and 1 or more deaths.

Source of admission: *home, nursing home, general hospital, academic or top-clinical hospital*.

This variable indicates the patient's location before the admission.

Year of discharge: *2008, 2009, 2010, 2011*.

Inclusion of the year guarantees the number of observed and expected (predicted) deaths to be equal for that year. This makes 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 LMR participation, data quality and casemix. In addition to this, only HSMRs were calculated for hospitals that authorized CBS to deliver 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 then. Actually, these hospitals do not belong to the HSMR population. Therefore, a code "0" has been assigned to this criterion.

Insufficient participation in the LMR

1. Hospitals with a LMR response rate of less than 50% for inpatient admissions are excluded (criterion 2009-2010). In 2011 hospitals with less than 6 completely registered months (for inpatient admissions) are excluded.

Data quality

Hospitals are excluded if*:*

2. ≥2% of the inpatient admissions have a vague diagnosis code (ICD9-CM codes 799.8 and 799.9).
3. ≤30% of the inpatient admissions are coded as acute (not planned).
4. ≤0.5 secondary diagnoses are registered per inpatient admission, on average per hospital.[5]

Casemix

Hospitals are excluded if:

5. The expected mortality is 50 or less, i.e. $E_{dh} \leq 50$.
6. ≤70% of the inpatient hospital deaths are within the 50 CCS diagnosis groups considered.

In addition to the above mentioned criteria, hospitals are also excluded if they did not authorize CBS to deliver their HSMR figures.

Table A2.1 gives a summary of the hospitals by the different criteria for exclusion for 2011, and Table A2.2 for 2009-2011. (H)SMRs for 2009-2011 are only calculated if hospitals fulfil the criteria in 2011 and in the three year period as a whole, and have responded in all three years.

[5] For this criterion all secondary diagnoses are considered, also when they do not belong to the 17 comorbidity groups that are used as covariates. If identical secondary diagnoses (identical ICD9-CM codes) are registered within one admission, only one is counted. If a secondary admission 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, 2011

No.	Criterion	Authorization	No authorization	Total hospitals
0	No inpatient admissions	1	0	1
1	No/partial participation (<50%) LMR	6	5	11
	of which no participation	*4*	*5*	*9*
	of which partial response (<6 months complete registration)	*2*	*0*	*2*
2	≥2% vague diagnosis code	0	0	0
3	≤30% admissions coded as acute	0	0	0
4	≤ 0.5 secondary diagnoses per inpatient admission (average per hospital)	0	0	0
5	≤50 expected mortality	0	0	0
6	≤ 70% hospital deaths within the 50 diagnosis groups considered	1	1	2
	Does not fulfil >1 of above-mentioned exclusion criteria (1-6)	3	1	4
	Meet all criteria	77[a)]	1	78
	Total hospitals	88	8	96

a) For one hospital (H)SMRs are calculated although it had <6 months of complete registration in 2011. This hospital had a response of >50%, not selective with respect to mortality. For one hospital (H)SMRs are calculated although the percentage of deaths in the 50 diagnosis groups was slightly lower than 70% in 2011. For another hospital (H)SMRs are calculated although the expected mortality was <50 (due to small size of the hospital and only 6 months of registration). These hospitals are grouped under "Meet all criteria".

From Table A2.1 it can be concluded that 77 hospitals met all criteria in 2011 and have given authorization. For the period 2009-2011 this is the case for 67 hospitals (see Table A2.2). So HSMR 2011 figures were produced for 77 hospitals, and HSMR 2009-2011 figures for 67 hospitals.

Table A2.2. Number of hospitals according to exclusion criteria, 2009-2011

No.	Criterion	Authorization	No authorization	Total hospitals
0	No inpatient admissions	1	0	1
1	No/partial participation (<50%) LMR	11	4	15
	of which no participation in one or more years	*9*	*4*	*13*
	of which partial response in one or more years	*2*	*0*	*2*
2	≥2% vague diagnosis code	1	0	1
3	≤30% admissions coded as acute	0	0	0
4	≤ 0,5 secondary diagnoses per inpatient admission (average per hospital)	2	0	2
5	≤50 expected mortality	0	0	0
6	≤ 70% hospital deaths within the 50 diagnosis groups considered[b)]	1	1	2
	Does not fulfil >1 of above-mentioned exclusion criteria (1-6)	5	2	7
	Meet all criteria	67[a)]	1	68
	Total hospitals	88	8	96

a) For one hospital (H)SMRs are calculated although the percentage of deaths in the 50 diagnosis groups was slightly lower than 70% in 2009-2011. For another 2 hospitals (H)SMRs 2009-2011 are calculated although only 3 complete months were registered in 2010 (see section 2.1.1). 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)

No. CCS-group	Age	Sex	SES	Severity of main diagnosis	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*	Source of admission	Year of discharge	Month of admission
2	1	1	1	1	0	1	1	1	1	0	1	0	0	1	0	0	0	1	1	-	1	1	1	1	1
12	0	0	0	0	1	1	1	0	1	-	1	-	-	-	0	-	-	1	0	-	1	-	1	1	0
13	1	1	1	0	1	1	1	1	1	-	1	-	0	-	0	-	-	1	0	-	1	-	0	0	0
14	1	1	1	1	1	1	1	0	1	0	1	0	1	1	0	1	-	1	1	-	1	-	1	1	0
15	1	1	0	0	1	1	1	0	1	0	1	-	-	-	0	-	-	1	0	-	1	-	1	1	0
17	1	0	0	1	1	1	-	1	1	-	1	-	-	-	0	-	-	1	0	-	1	-	0	1	0
19	1	1	0	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	-	1	-	1	1	1
24	1	0	0	1	1	0	0	0	1	0	0	0	-	-	0	-	-	1	0	-	1	-	0	1	0
29	1	-	0	0	1	1	1	0	1	-	0	-	-	-	0	-	-	1	0	-	1	-	0	1	0
32	1	0	0	1	1	1	1	0	1	0	1	-	-	-	1	-	-	1	1	-	1	-	0	1	0
38	1	0	1	1	1	1	1	0	1	-	1	0	1	-	0	-	-	1	1	0	1	-	1	1	0
39	1	0	1	1	1	1	1	0	1	-	1	0	-	-	0	-	-	1	1	-	0	-	1	1	0
42	1	0	1	1	1	1	1	1	1	0	1	0	1	-	0	0	0	1	0	-	1	1	1	1	0
44	1	0	0	1	1	1	1	0	1	0	0	0	-	-	0	-	0	1	1	-	1	-	0	1	0
50	1	1	0	1	1	1	1	1	0	0	1	0	-	1	0	0	0	1	1	-	1	-	0	1	0
55	1	1	1	1	0	0	1	0	0	0	1	0	-	1	0	0	0	0	1	-	1	-	0	1	0
59	1	1	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	1	1	-	1	0	1	1	0
85	1	0	0	1	1	1	1	-	1	1	1	-	-	-	0	-	-	1	1	-	1	-	0	0	1
96	1	0	0	1	1	1	1	1	1	0	0	0	1	-	0	0	0	1	0	-	0	-	1	1	0
100	1	0	1	1	1	1	1	1	1	1	1	0	0	-	0	1	1	1	1	-	1	-	1	1	0
101	1	0	0	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	1	-	1	-	1	1	0
103	1	0	0	1	1	1	1	0	1	1	1	0	-	1	0	-	-	1	1	-	1	-	1	1	0
106	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	-	1	-	1	1	1

No. CCS-group	Age	Sex	SES	Severity of main diagnosis	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*	Source of admission	Year of discharge	Month of admission
107	1	0	1	1	1	1	0	0	1	-	1	-	-	-	1	-	-	1	1	-	1	-	1	1	1
108	1	1	1	-	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	-	1	-	1	1	1
109	1	0	1	1	1	1	1	1	0	1	1	0	1	1	0	0	0	1	1	-	1	-	1	1	1
114	1	1	0	1	1	1	1	1	1	0	1	1	1	0	0	0	-	1	1	-	1	-	1	1	1
115	1	1	1	1	1	1	1	0	1	1	1	0	0	-	0	-	1	1	1	-	1	-	0	1	0
116	1	1	0	1	1	1	1	1	1	0	1	0	-	-	0	0	0	1	1	-	1	-	0	1	0
117	1	0	1	1	1	0	1	1	1	0	0	0	-	-	0	0	-	1	1	-	1	-	1	1	1
122	1	1	0	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	1	1	1	1	1
127	1	0	0	1	1	1	1	1	1	0	1	0	-	1	0	0	0	1	1	-	1	-	1	1	1
129	1	0	0	-	0	1	1	1	0	0	1	-	-	-	0	-	1	0	1	-	1	-	0	1	0
130	1	0	0	1	1	0	1	0	0	0	1	0	-	1	0	-	-	1	1	-	1	-	1	1	0
133	1	1	0	1	1	0	1	1	1	1	1	0	-	1	0	0	1	1	1	-	1	-	1	1	1
145	1	0	0	1	0	0	1	1	1	1	1	1	-	1	1	0	0	1	1	-	1	-	0	1	0
146	1	0	0	1	1	1	1	0	1	1	1	1	-	-	0	-	-	1	1	-	1	-	1	1	0
149	1	0	1	1	1	1	1	0	1	0	1	0	1	1	0	1	0	1	1	-	1	1	1	1	0
150	0	0	0	1	1	1	1	-	-	-	0	-	1	0	0	-	-	1	1	-	-	1	0	0	0
151	1	0	0	1	1	0	1	0	1	0	1	1	0	1	0	0	-	1	1	-	1	1	1	1	0
153	1	1	0	1	1	1	1	1	1	1	1	0	0	1	0	0	-	1	1	-	1	1	1	1	1
155	1	0	0	1	1	0	1	1	1	0	0	0	0	1	0	0	0	1	1	-	1	-	1	1	0
157	1	0	1	0	1	1	1	1	0	0	0	0	0	1	0	0	-	0	1	-	1	-	1	1	1
158	1	1	0	1	1	1	1	1	0	0	1	0	-	-	0	0	-	0	1	-	1	-	1	1	0
159	1	1	0	1	1	1	1	1	1	0	1	0	1	1	0	0	0	1	1	-	1	-	1	1	1
226	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	1	-	1	-	1	1	0
233	1	1	1	1	1	1	1	0	1	0	0	0	-	1	1	0	0	1	0	-	1	-	1	1	0
237	1	1	0	1	1	1	1	1	1	1	1	1	-	1	0	0	0	1	1	-	1	-	1	1	0
238	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	-	1	-	1	1	0
249	1	0	0	-	0	1	1	0	0	-	1	-	1	1	1	-	-	1	1	-	1	-	1	1	0
Total	48	21	18	42	44	40	47	28	41	16	40	7	17	26	7	6	5	46	41	0	47	7	36	47	15

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

A. Wald statistics

No. CCS-group	Age	Sex	SES	Severity of main diagnosis	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*	Source of admission	Year of discharge	Month of admission
2	951	18	12	1000	2	11	81	39	20	2	11	0	3	81	0	0	1	41	69	-	70	8	19	37	26
12	20	1	4	0	330	11	17	3	8	-	4	-	-	-	0	-	-	4	0	-	66	-	17	11	4
13	88	6	12	0	337	7	10	5	8	-	16	-	1	-	1	-	-	28	1	-	82	-	1	7	2
14	492	21	16	37	724	32	123	4	13	1	8	0	12	60	1	4	-	58	9	-	269	-	9	30	10
15	157	8	7	5	307	21	44	0	14	3	9	-	-	-	0	-	-	44	1	-	57	-	31	22	2
17	44	0	3	16	206	15	-	6	15	-	9	-	-	-	1	-	-	28	0	-	98	-	6	17	1
19	224	9	7	124	3867	23	111	20	37	1	29	0	18	42	0	0	0	79	18	-	281	-	61	57	25
24	24	0	4	40	990	2	2	0	4	0	1	0	-	-	1	-	-	16	0	-	238	-	4	17	2
29	49	-	3	3	289	20	21	0	8	-	3	-	-	-	0	-	-	20	0	-	167	-	1	34	2
32	39	3	8	40	717	7	26	1	6	2	8	-	-	-	5	-	-	28	12	-	207	-	4	21	3
38	142	0	10	52	464	11	45	0	6	-	8	3	8	-	0	-	-	58	29	1	21	-	89	11	5
39	316	1	12	88	270	7	41	0	70	-	11	2	-	-	1	-	-	39	7	-	3	-	34	18	0
42	252	0	16	116	1809	15	152	14	60	3	16	3	14	-	0	0	3	87	0	-	297	34	18	62	9
44	73	0	3	53	142	6	21	2	12	0	3	1	-	-	0	-	2	14	4	-	8	-	7	27	9
50	268	4	3	148	53	61	109	24	1	3	9	1	-	23	0	0	0	37	26	-	6	-	7	33	8
55	382	21	12	540	1	2	110	1	2	3	7	2	-	24	1	0	1	0	30	-	32	-	1	44	10
59	79	11	0	129	90	1	142	1	13	0	3	0	2	1	0	0	0	7	12	-	27	0	25	38	8
85	112	0	2	439	16	5	22	-	4	5	7	-	-	-	0	-	-	4	5	-	17	-	6	2	11
96	285	0	9	200	122	13	126	18	37	3	0	3	18	-	0	2	2	109	4	-	2	-	87	65	9
100	1752	0	24	606	27	19	520	20	105	14	33	0	3	-	0	9	18	159	47	-	36	-	35	70	11
101	752	0	6	94	90	11	386	15	51	23	42	1	30	18	1	21	0	103	20	-	15	-	155	61	6
103	379	1	4	82	13	32	110	0	82	10	10	0	-	13	0	-	-	15	27	-	68	-	45	24	8
106	834	19	30	937	87	1	254	11	45	12	61	0	29	17	12	20	1	85	48	-	47	-	24	106	18
107	245	0	12	771	144	24	2	2	13	-	33	-	-	-	10	-	-	14	13	-	5	-	76	18	12
108	1410	30	16	-	105	38	11	26	185	20	79	6	29	48	0	0	1	549	45	-	77	-	66	142	48
109	2528	0	12	7465	41	96	488	10	1	13	62	2	9	19	0	3	1	54	150	-	95	-	43	105	14

No. CCS-group	Age	Sex	SES	Severity of main diagnosis	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*	Source of admission	Year of discharge	Month of admission
114	432	5	4	1151	454	50	117	44	20	1	18	8	15	2	3	1	-	82	15	-	19	-	41	33	16
115	784	16	10	1631	436	13	13	2	8	6	19	1	1	-	1	-	5	23	4	-	8	-	5	20	4
116	232	10	5	223	364	14	106	35	37	1	12	1	-	-	3	1	0	82	17	-	15	-	4	36	5
117	149	0	10	249	24	0	57	36	4	3	2	2	-	-	2	0	-	29	18	-	30	-	25	21	13
122	3572	35	11	190	0	135	541	36	183	71	37	5	9	113	0	0	1	169	388	1	241	9	72	163	33
127	569	4	11	83	112	19	266	14	26	0	21	0	-	18	2	0	0	71	43	-	19	-	48	40	64
129	205	1	4	-	0	7	22	4	1	0	5	-	-	-	2	-	6	0	9	-	28	-	8	15	7
130	351	1	1	47	78	0	17	1	1	2	41	2	-	26	0	-	-	35	27	-	63	-	29	28	10
133	1084	11	8	1202	707	3	195	4	18	10	71	2	-	79	1	2	8	42	255	-	135	-	147	115	20
145	1150	0	3	290	2	4	73	10	18	12	73	6	-	20	5	1	1	57	47	-	95	-	4	56	3
146	374	4	5	164	26	16	93	1	6	11	15	9	-	-	0	-	-	45	37	-	38	-	12	29	7
149	569	1	11	219	34	19	136	1	20	1	9	0	11	18	2	10	1	137	15	-	60	13	14	40	8
150	5	0	6	29	79	5	21	-	-	-	0	-	6	0	0	-	-	39	7	-	-	107	5	8	5
151	169	0	2	558	93	0	18	3	11	1	5	6	1	9	1	0	-	103	10	-	45	43	32	24	3
153	328	15	9	336	10	8	176	14	34	10	22	0	2	68	3	3	-	55	89	-	45	6	14	55	16
155	317	0	1	1311	31	2	21	7	5	3	3	3	1	14	1	1	0	28	21	-	67	-	14	14	5
157	367	1	13	0	40	10	98	6	3	2	2	3	0	24	0	1	-	3	7	-	38	-	28	32	13
158	289	10	4	9	301	11	42	24	4	0	5	0	-	-	2	0	-	1	6	-	8	-	35	32	4
159	609	7	2	74	26	24	156	17	60	2	13	0	16	19	2	0	1	45	9	-	55	-	30	35	14
226	916	295	2	10	5	116	870	13	81	10	65	0	50	82	3	6	2	183	35	-	33	-	9	118	11
233	527	23	11	2734	12	6	70	1	15	1	3	0	-	21	4	0	1	9	0	-	24	-	18	16	5
237	384	17	3	293	158	13	230	28	31	18	41	13	-	60	1	0	1	31	14	-	24	-	69	24	11
238	669	2	13	502	15	11	102	21	14	4	16	0	17	50	14	1	13	94	65	-	32	-	204	25	5
249	246	2	1	-	2	19	11	2	1	-	11	-	5	23	5	-	-	4	20	-	27	-	10	13	4
Total	26194	612	396	24294	14253	996	6424	546	1421	289	992	87	310	993	94	86	71	3050	1739	2	3440	220	1747	2072	549

B. Degrees of freedom

No. CCS-group	Age	Sex	SES	Severity of main diagnosis	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*	Source of admission	Year of discharge	Month of admission
2	20	1	4	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	3	3	5
12	11	1	4	1	1	1	1	1	1	-	1	-	-	-	1	-	-	1	1	-	1	-	2	3	5
13	13	1	4	1	1	1	1	1	1	-	1	-	1	-	1	-	-	1	1	-	1	-	2	3	5
14	14	1	5	3	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	-	1	-	2	3	5
15	11	1	4	2	1	1	1	1	1	1	1	-	-	-	1	-	-	1	1	-	1	-	2	3	5
17	11	1	4	2	1	1	-	1	1	-	1	-	-	-	1	-	-	1	1	-	1	-	2	3	5
19	13	1	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	3	3	5
24	13	1	4	2	1	1	1	1	1	1	1	1	-	-	1	-	-	1	1	-	1	-	1	3	5
29	9	-	4	1	1	1	1	1	1	-	1	-	-	-	1	-	-	1	1	-	1	-	1	3	5
32	11	1	4	2	1	1	1	1	1	1	1	-	-	-	1	-	-	1	1	-	1	-	2	3	5
38	18	1	4	5	1	1	1	1	1	-	1	1	1	-	1	-	-	1	1	1	1	-	3	3	5
39	19	1	5	6	1	1	1	1	1	-	1	1	-	-	1	-	-	1	1	-	1	-	3	3	5
42	18	1	5	4	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	-	1	1	3	3	5
44	18	1	4	3	1	1	1	1	1	1	1	1	-	-	1	-	1	1	1	-	1	-	3	3	5
50	15	1	5	4	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	3	3	5
55	16	1	4	3	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	3	3	5
59	18	1	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	3	3	5
85	19	1	4	1	1	1	1	-	1	1	1	-	-	-	1	-	-	1	1	-	1	-	3	3	5
96	17	1	5	4	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	-	1	-	3	3	5
100	15	1	5	2	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	-	1	-	3	3	5
101	13	1	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	3	3	5
103	18	1	4	3	1	1	1	1	1	1	1	1	-	1	1	-	-	1	1	-	1	-	3	3	5
106	19	1	5	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	3	3	5
107	14	1	4	2	1	1	1	1	1	-	1	-	-	-	1	-	-	1	1	-	1	-	3	3	5
108	17	1	5	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	3	3	5

No. CCS-group	Age	Sex	SES	Severity of main diagnosis	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*	Source of admission	Year of discharge	Month of admission
109	20	1	5	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	3	3	5
114	16	1	4	4	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	-	1	-	3	3	5
115	13	1	4	5	1	1	1	1	1	1	1	1	1	-	1	-	1	1	1	-	1	-	3	3	5
116	13	1	4	3	1	1	1	1	1	1	1	1	-	-	1	1	1	1	1	-	1	-	2	3	5
117	17	1	4	4	1	1	1	1	1	1	1	1	-	-	1	1	-	1	1	-	1	-	3	3	5
122	20	1	5	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	5
127	15	1	5	3	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	3	3	5
129	18	1	4	-	1	1	1	1	1	1	1	-	-	-	1	-	1	1	1	-	1	-	3	3	5
130	16	1	4	3	1	1	1	1	1	1	1	1	-	1	1	-	-	1	1	-	1	-	3	3	5
133	20	1	5	4	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	3	3	5
145	16	1	5	3	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	3	3	5
146	11	1	4	2	1	1	1	1	1	1	1	1	-	-	1	-	-	1	1	-	1	-	2	3	5
149	14	1	5	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	3	3	5
150	10	1	4	1	1	1	1	-	-	-	1	-	1	1	1	-	-	1	1	-	-	1	2	3	5
151	18	1	4	6	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	-	1	1	3	3	5
153	13	1	5	5	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	-	1	1	3	3	5
155	16	1	4	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	3	3	5
157	18	1	4	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	-	1	-	3	3	5
158	16	1	4	1	1	1	1	1	1	1	1	1	-	-	1	1	-	1	1	-	1	-	3	3	5
159	15	1	5	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	3	3	5
226	10	1	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	3	3	5
233	20	1	5	8	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	3	3	5
237	17	1	5	3	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	3	3	5
238	19	1	4	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	3	3	5
249	14	1	4	-	1	1	1	1	1	-	1	-	1	1	1	-	-	1	1	-	1	-	3	3	5
Total	775	49	219	143	50	50	49	48	49	41	50	39	26	29	50	31	27	50	50	2	49	8	137	150	250

* 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

Summaries of individual models

In “Coefficients HSMR 2011.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.