Statistics Netherlands

Statistics Methods

HSMR 2012: Methodological report

2013 | 10

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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
2012–2013	2012 to 2013 inclusive
2012/2013	Average for 2011 to 2012 inclusive
2012/'13	Crop year, financial year, school year, etc., beginning in 2012 and ending in 2013
2010/'11–2012/'13	Crop year, financial year, etc., 2010/'11 to 2012/'13 inclusive

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

Publisher
Statistics Netherlands
Henri Faasdreef 312, 2492 JP The Hague
www.cbs.nl

Prepress: Statistics Netherlands, Grafimedia
Design: Edenspiekermann

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Fax +31 45 570 62 68
ISSN 1876-0333

60165 201303 X-37

Contents

Tables

Figures

Files

Coefficients HSMR 2012.xls

Classification of variables HSMR 2012.xls`

(see auxiliary files published with this report on www.cbs.nl)

1. Introduction

Just as for 2008-2010 (CBS, 2011) and 2009-2011 (CBS, 2012), Statistics Netherlands (CBS) has calculated the Hospital Standardised Mortality Ratios (HSMRs) for Dutch hospitals for the period 2010-2012. The HSMRs are ratios of observed and expected number of deaths and aim to present comparable hospital mortality figures. This report describes the methods used. As they are very similar to those used for the previous periods, the results of the models for the three periods can easily be compared. For the sake of clarity, this report follows the same structure and contents as of the previous reports. In the present model, the categorisation of the covariate Source of admission has been modified, see chapter 2 and Appendix 1. The transition from ICD9-CM to ICD10 coding by almost half the hospitals in 2012 had an impact on the HSMRs for 2012. This is described in section 3.4.

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 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 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

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

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 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

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

in which both the numerator and denominator are sums across all admissions for all considered diagnoses. The HSMR 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 many other countries, the Netherlands is very interested in measuring the quality of health care. Hospitals can be assessed on 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.

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 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 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), 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 (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 branch associations. The model for the HSMR 2009-2011 was nearly identical to that for 2008-2010, while the model for the HSMR 2010-2012 did not undergo any changes apart from the different categorisation of the variable 'Source of admission'.

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

[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.

request for authorisation was sent only to hospitals that had not previously authorised CBS and that participated in the 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. The authorisation request to the hospitals also declared that CBS will not publish data on identifiable hospitals, but that the hospital branch associations governing DHD (i.e. NVZ – *Nederlandse Vereniging van Ziekenhuizen*, and NFU – *Nederlandse Federatie van Universitair Medische Centra*) could decide to publish individual hospital data, in consultation with the hospitals.

1.5 CBS output

CBS estimated the models for expected mortality per diagnosis for 2010-2012. 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 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 LMR data were not too deviant in some respects (see Appendix 2).

CBS 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 2010-2012 and the individual years. SMRs are also presented for different patient groups (by age, sex and urgency of admission). 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.

   From this period onwards, these reports also contain SMRs for the following clusters of CCS diagnosis groups: neoplasms; diseases of the circulatory system; respiratory diseases; diseases of stomach, intestines and liver; and diseases of the genitourinary system. These clusters are not complete with respect to diseases, but are restricted to the selection of 50 CCS diagnosis groups that are part of the HSMR. As these SMRs are combinations of several CCS diagnosis groups, confidence intervals are smaller than for the specific SMRs for each CCS group.
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 2010-2012 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 there is still lack of consistency in coding practice.
- 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 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 may diminish this problem (see chapter 5).
- There appear to be some differences in the HSMR for 2012 between hospitals that code in ICD10 and those that code in ICD9. The average HSMR of ICD10 coding hospitals seems to be a few points lower than that of ICD9 coding hospitals. This is probably partly connected with the switch from ICD9 to ICD10. For more information see section 3.4.

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 LMR as covariates.

The regression models for the (H)SMR 2010-2012 and the (H)SMRs of the individual years use LMR data for the last four years, i.e. the period 2009-2012. The addition of 2009 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.

There are two minor differences with respect to the methods used last year (CBS, 2012):

- Hospitals are in transition from coding diagnoses in ICD9-CM to coding in ICD10 (International Classification of Diseases, 10th Revision). In 2012 38 hospitals (of 84 in the HSMR model) registered all or part of the diagnoses in ICD10. After research CBS decided to first convert these ICD10 codes to ICD9-CM using a Dutch conversion table[2], and then use the ICD9-CM definitions of the HSMR variables also used for hospitals still coding in ICD9-CM. This method was also used in the previous model (CBS, 2012) for the very few hospitals that coded in ICD10 in 2011, but for 2012 one exception was made in the conversion: comorbidities coded with ICD10 code Z95.5 were skipped, as otherwise the corresponding converted ICD9-CM code (V434) would incorrectly fall into the Charlson comorbidity group 'peripheral vascular disease', resulting in too large numbers of comorbidities in this group for the hospitals coding in ICD10. The mix of hospitals coding in ICD9-CM and in ICD10 appeared to have an effect on the HSMR 2012 outcomes: hospitals coding in ICD10 had lower HSMRs, on average. This is further analysed in section 3.4.

- The categorisation of the variable 'Source of admission' was adapted, in preparation of the transition of the LMR to a new registration model from 2013 onwards (see section 2.4).

For the sake of continuity, it was decided to implement only these necessary changes in the model this year. At the same time, research will be initiated to develop the HSMR model further in the coming years (see chapter 5).

[2] Conversion table 'ICD-10 – CvZ80', see http://www.rivm.nl/who-fic/ICD.htm

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 LMR. However, not all hospitals participate in the LMR. Table 1 gives the response numbers for 2012.

Table 1. Participation of hospitals in the LMR 2012

Type of hospital	Total hospital population	LMR population	Total hospitals participating in LMR	Participating hospitals with partial response
General hospitals	84	84	75	18
University hospitals	8	8	8	2
Specialised hospitals	8[a)]	4[b)]	2	0
Total hospitals	100	96	85	20

a) Excluding hospitals with a long-stay character, i.e. epilepsy clinics, long-stay centres for rehabilitation, and asthma treatment centres. Private and semi-private clinics are also excluded, as they mainly treat outpatients and day cases.
b) Including specialised hospitals for (1) lung diseases, (2) cancer, (3) rheumatic diseases, orthopaedics and rehabilitation, and (4) eye diseases.

In principle, the HSMR model includes all short-stay hospitals with inpatient admissions participating in the LMR in 2009-2012. The target population thus includes all general, university and short-stay specialised hospitals with inpatient admissions. One of the 85 hospitals participating in the LMR has day admissions only, and is therefore excluded from the model. Eleven hospitals did not participate in the LMR in 2012. The admissions of these hospitals cannot be analysed. Another twenty hospitals were partial non-respondents in 2012, 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 dataset, 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 some hospitals, see below). In total, the number of hospitals included in the HSMR model was 84 in 2012, 86 in 2011, 83 in 2010 and 82 in 2009.

The model included only the fully registered months for four partially non-responding hospitals in 2012, for one partially non-responding hospital in 2011, and for two partially non-responding hospitals in 2010, 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 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 2012 population of hospital stays comprises all inpatient admissions that ended in 2012. 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 80.6% of entire inpatient hospital mortality and 36.3% of inpatient admissions in 2010-2012. Moreover, some registered admissions of two partially non-responding hospitals in 2010, one partially non-responding hospital in 2011 and four partially non-responding hospitals in 2012 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 (28,777 inpatient admissions in 2009-2012).

Altogether, we included in the 2009-2012 model 2,458,426 inpatient admissions registered in the 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 2,458,426 inpatient admissions mentioned in section 2.1 is 4.3%. 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[3]) 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 codes of these 50 CCS groups are available in a separate file published together with this report.

These 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 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 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 2011 and 2012 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 (planned, not planned);
- 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. 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 was suggested by Lingsma and Pouw, who did research for the Dutch HSMR Expert group; see Appendix 1.
- Source of admission (3 categories: home, nursing home or other institution, hospital), indicating the patient's location before the admission. In former years, a distinction was made between 'general hospitals' and 'academic or top-clinical hospitals'; see Appendix 1.

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

- Year of discharge (4 categories: 2009-2012);
- 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

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

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 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 also place when there were no deaths in the category. All regression coefficients are presented in the file "Coefficients HSMR 2012.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 2012.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

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

where $HSMR_h^{-x_j}$ is the HSMR that would result from deletion of covariate x_j, and N=77 the total number of hospitals for which an HSMR was calculated for 2012.

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.

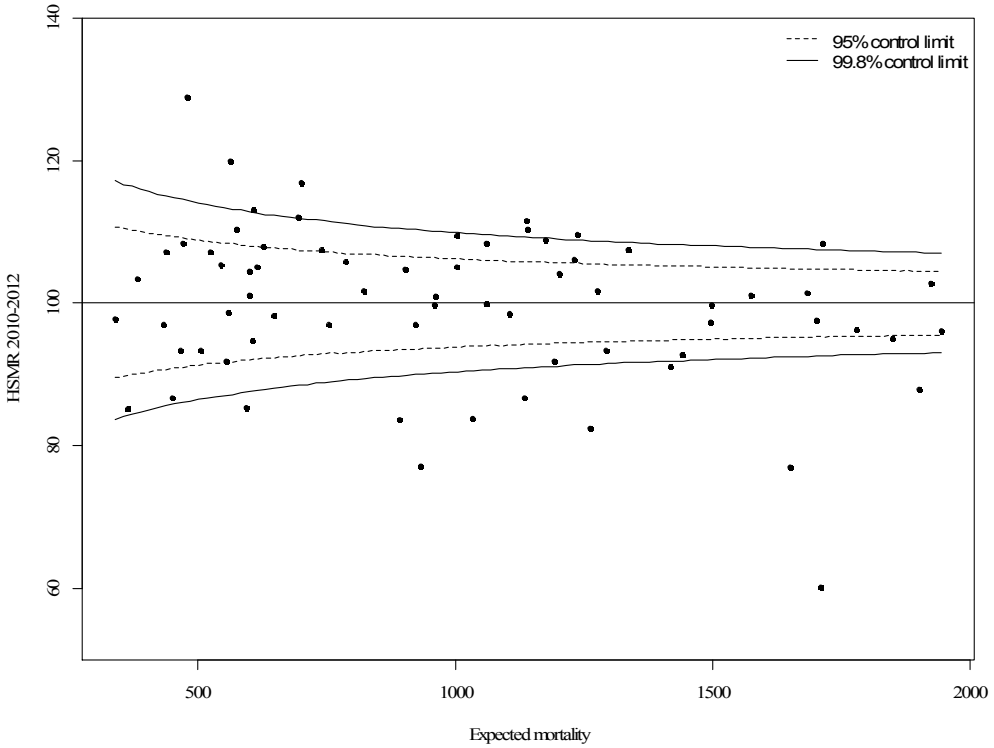
2.5.3 Confidence intervals and control limits

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 2010-2012, 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 2010-2012 it is 98.3 (n=69 hospitals). For the year 2012 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 2010-2012



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. 2009-2011 and 2010-2012) 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 2012 not presented here). Observed mortality (numerator) and expected mortality (denominator) are then calculated for the 2012 admissions, whereas the expected mortality model of the HSMR still uses the 2009-2012 data. If a hospital has a significantly high HSMR in 2012, but not for 2010-2012, 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 2010-2012, but not in 2012, this does not necessarily mean that the situation improved in 2012, 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's 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 2012.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 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 several of the comorbidity groups, especially groups 2, 13 and 16, i.e. for Congestive heart failure, Renal disease and Metastatic cancer. 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.

Table 2. Statistical significance of the covariates for the 50 logistic regressions (summary), HSMR 2012 model

Covariate	No. of significant results	Covariate	No. of significant results
Age	48	Comorbidity_9	31
Comorbidity_2	48	Comorbidity_5	27
Comorbidity_13	47	Month of admission	20
Comorbidity_16	47	Sex	19
Year of discharge	47	Comorbidity_8	17
Urgency	43	Comorbidity_10	16
Comorbidity_4	43	SES	13
Comorbidity_6	43	Comorbidity_12	9
Severity main diagnosis	42	Comorbidity_7	8
Comorbidity_14	42	Comorbidity_17	8
Comorbidity_1	40	Comorbidity_11	7
Source of admission	35	Comorbidity_15	0
Comorbidity_3	34		

Compared with the model results for the HSMR 2009-2011 (CBS, 2012), several comorbidities are more often significant, as a result of an increase in registered comorbidities. Note that in the new HSMR model we added 2012 and removed 2008.

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 3 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 Age has the highest explanatory power, with 24,145 as the sum of the Wald statistics. But Age also has by far the most parameters. Severity of main diagnosis has only a slightly smaller Wald statistic, but has much fewer categories. Urgency of admission is also an important variable. The explanatory powers of Month of admission, Sex and SES are relatively small. This is also true for some comorbidity groups. As 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 equals 22,314 with 668 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.

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

Table 4 shows the impact of each covariate on the HSMR 2012, as measured by formula (3.1) for the 77 hospitals for which HSMRs are calculated. Age and Severity of the main diagnosis had the largest effect on mortality (for the years 2009-2012), but their impact on *hospital* mortality is smaller, apparently as a result of relatively small differences in their distributions between hospitals. Comorbidity

Table 3. Wald chi-square statistics for the 50 logistic regressions, HSMR 2012 model

Covariate	Sum of Wald statistics	Sum of df	Covariate	Sum of Wald statistics	Sum of df
Age	24145	772	Comorbidity_1	1009	50
Severity main diagnosis	23922	144	Comorbidity_3	615	49
			Month of admission	600	250
Urgency	13439	50	Sex	548	49
Comorbidity_2	6812	50	Comorbidity_5	415	43
Comorbidity_16	3696	49	SES	373	220
Comorbidity_13	3024	50	Comorbidity_8	319	26
Year of discharge	1984	150	Comorbidity_17	270	9
Comorbidity_14	1705	50	Comorbidity_10	195	50
Source of admission	1688	98	Comorbidity_11	125	35
Comorbidity_4	1423	49	Comorbidity_12	115	30
Comorbidity_9	1270	34	Comorbidity_7	113	42
Comorbidity_6	1207	50	Comorbidity_15	1	2

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 2012. 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. 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 in the future.

Table 4. Average shift in HSMR 2012 by inclusion/deletion of covariates

Covariate	Average shift in HSMR	Covariate	Average shift in HSMR
Comorbidity [a)]	8.82	SES	1.00
Age	4.72	Source of admission	0.61
Urgency	2.72	Month of admission	0.50
Severity main diagnosis	2.62	Sex	0.13

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

3.2 Model evaluation for the 50 regression analyses

Table 5 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 in CBS (2012). Only "Cancer of esophagus" differs by more than .02.

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" and "Cancer of breast" (C=.93), "Biliary tract disease" and "Other gastrointestinal disorders" (C=.92), "Cancer of

bladder" and "Peripheral and visceral atherosclerosis" (C=.91). For these six CCS groups the covariates strongly reduce the uncertainty in predicting patient mortality. The lowest values are found for "Congestive heart failure; non-hypertensive" (C=.67), "Aspiration pneumonitis; food/vomitus" (C=.68), "Chronic obstructive pulmonary disease and bronchiectas" (C=.71) and "Liver disease; alcohol-related" (C=.72).

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)	18980	4743	0,77
12	Cancer of esophagus	10281	655	0,77
13	Cancer of stomach	14306	694	0,80
14	Cancer of colon	40896	1880	0,81
15	Cancer of rectum and anus	21015	631	0,81
17	Cancer of pancreas	11245	946	0,74
19	Cancer of bronchus; lung	74466	5249	0,83
24	Cancer of breast	55248	519	0,93
29	Cancer of prostate	23438	518	0,90
32	Cancer of bladder	42036	547	0,91
38	Non-Hodgkins lymphoma	19924	950	0,82
39	Leukaemias	19237	1156	0,83
42	Secondary malignancies	70987	4650	0,78
44	Neoplasms of unspecified nature or uncertain behaviour	18818	395	0,83
50	Diabetes mellitus with complications	31848	546	0,87
55	Fluid and electrolyte disorders	26950	971	0,83
59	Deficiency and other anaemia	47214	530	0,79
85	Coma; stupor; and brain damage	4213	569	0,81
96	Heart valve disorders	34836	1194	0,80
100	Acute myocardial infarction	93216	5117	0,78
101	Coronary atherosclerosis and other heart disease	207828	1501	0,80
103	Pulmonary heart disease	28244	1187	0,79
106	Cardiac dysrhythmias	198507	1434	0,87
107	Cardiac arrest and ventricular fibrillation	9059	3883	0,76
108	Congestive heart failure; nonhypertensive	101040	10125	0,67
109	Acute cerebrovascular disease	96311	12385	0,78
114	Peripheral and visceral atherosclerosis	39062	1725	0,91
115	Aortic; peripheral; and visceral artery aneurysms	26798	2689	0,89
116	Aortic and peripheral arterial embolism or thrombosis	28821	659	0,89
117	Other circulatory disease	22199	516	0,87
122	Pneumonia (except that caused by tuberculosis or sexually transmitted diseases)	125396	10307	0,78
127	Chronic obstructive pulmonary disease and bronchiectas	81278	3633	0,71
129	Aspiration pneumonitis; food/vomitus	5098	1295	0,68
130	Pleurisy; pneumothorax; pulmonary collapse	22919	821	0,84

CCS-group no.	Description CCS diagnosis group	Number of admissions	Number of deaths	C-statistic
133	Other lower respiratory disease	104851	3822	0,86
145	Intestinal obstruction without hernia	32160	1758	0,85
146	Diverticulosis and diverticulitis	35005	570	0,86
149	Biliary tract disease	126185	714	0,92
150	Liver disease; alcohol-related	5217	647	0,72
151	Other liver diseases	16343	1058	0,82
153	Gastrointestinal haemorrhage	33734	1179	0,81
155	Other gastrointestinal disorders	51345	724	0,92
157	Acute and unspecified renal failure	12188	1082	0,76
158	Chronic renal failure	17452	611	0,86
159	Urinary tract infections	68553	1571	0,84
226	Fracture of neck of femur (hip)	66191	2575	0,80
233	Intracranial injury	59673	1744	0,93
237	Complication of device; implant or graft	81073	959	0,86
238	Complications of surgical procedures or medical care	73882	1117	0,87
249	Shock	2860	1349	0,74

3.3 Regression coefficients

The file "coefficients HSMR 2012.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 coefficients equal zero.

3.4 Effect of transition from ICD9-CM to ICD10 coding on HSMR outcomes

In 2012, 38 hospitals coded their diagnoses completely or partially in ICD10. The remaining hospitals still coded completely in ICD9-CM. In order to investigate the effect of this difference in coding system, the results of hospitals that coded (almost) completely in ICD10 in 2012 and completely in ICD9-CM in 2009 (23 hospitals) were compared to those of hospitals that coded completely in ICD9-CM (45 hospitals) in both years. We call the first group the ICD10 group and the second the ICD9 group.

In 2012 the average HSMR of the ICD10 group was 6 points lower than that of the ICD9 group. In previous years there was not much difference between the two groups: in 2011 the average HSMR of the ICD10 group was 1 point higher and in 2010 it was 2 points lower. From 2011 to 2012 the HSMRs of the ICD10 group decreased significantly (compared to the ICD9 group). Therefore, this decrease seems to be connected to the switch from ICD9 to ICD10.

There are several possible reasons why the average HSMR 2012 is lower for the ICD10 group. First, hospitals in the ICD10 group coded on average more Charlson comorbidities (0.28 per inpatient stay) than the ICD9 group (0.24 per inpatient stay). In 2011 these numbers were equal (0.21 per inpatient hospital stay). Since, the Charlson comorbidities have a strong effect on the HSMR, this could have contributed to the lower average HSMR. Secondly, the differences may also be caused by differences between the coding systems themselves. Certain diagnoses are coded in much more detail, or differently, in ICD10 than in ICD9. Therefore, an exact one-to-one translation from ICD10 to ICD9 is not always possible, but default choices had to be made in the ICD10-ICD9 conversion table used. One thing that is visible in the data is that the distribution of Severity of the main diagnosis can be quite different in certain CCS groups for the converted ICD10 diagnoses compared to the ICD9 coded diagnoses. This causes a decrease in the SMR's for the ICD10 group for certain CCS groups, and an increase for other CCS groups. In addition to shifts in severity, the differences between the diagnosis coding systems also cause certain hospital stays to be assigned to different CCS groups or different Charlson comorbidities.

For the calculation of the HSMR, the ICD10 codes were first converted to ICD9, and these codes were used to derive CCS groups, comorbidities and severity. Although it is possible to derive CCS groups and comorbidities directly from ICD10 codes, and we did investigate this option, this only increased the difference between the ICD10 and ICD9 groups. Therefore, we decided to convert to ICD9, which we also did for the previous year for the very few hospitals that coded in ICD10 in 2011. Only for the comorbidity group 'peripheral vascular disease' did we decide not to include ICD10 code Z95.5 (see Appendix 1). After converting to ICD9, this code would end up in this comorbidity group, while this (coronary) diagnosis clearly does not belong here. This would lead to a too large number of comorbidities for the ICD10 coding hospitals.

Once all hospitals have moved to ICD10 coding, the differences caused by differences in coding systems will disappear. That will be a good moment to switch to a method where the CCS groups and comorbidities are derived directly from ICD10 codes. However, it is not yet possible to derive Severity of the main diagnosis directly from the ICD10 code, as the severities are based on multiple years of historical ICD9 data (see Appendix 1). So a similar classification of severity in ICD10 can only be calculated when enough data coded in ICD10 are available. Until then we shall convert to ICD9 for this variable.

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 unplanned 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) shows that comorbidities in particular present a problem, as there is no 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 (yet) being measured in the LMR. Some factors will be hard to measure at all. But there are also potentially important variables that may be measured by the hospitals in future years. Palliative care, for example, 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).

- 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 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

CBS (2011) described some possible changes in the HSMR model and output in the future. This year we introduced the presentation of SMRs for clusters of CCS groups. Other presentations, for example by specialism, may be considered in the future. In the coming years we may also consider updating or expanding the "Top 50" diagnosis groups included in the HSMR. This will be especially relevant when all hospitals have moved to ICD10 coding.

An indicator including early post-discharge mortality, alongside in-hospital mortality, could be introduced to tackle the problem of variety in the availability of terminal care outside the hospital. Ploemacher et al. (2013) saw a decrease in the standardised in-hospital mortality in the Netherlands in 2005-2010, which may have been caused by an overall improved quality of care, but may also be partly explained by substitution of in-hospital mortality by outside-hospital mortality, possibly influenced 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 so-called "SHMI" (Summary Hospital-level Mortality Indicator) has been adopted, which includes mortality up to 30 days post-discharge (Campbell et al., 2011). In 2013/2014 CBS will investigate the desired definition and time-frame of an indicator including early post-discharge mortality in the Netherlands and the possibilities for regular implementation of such an indicator. The latter also depends on full coverage of the registration of a unique identifier in the LMR which can be linked by CBS to date of death in the population register.

6. References

Bottle, A., Jarman B. and P. Aylin (2011). Hospital standardized mortality ratios: sensitivity analyses on the impact of coding. Health Serv Res 46(6 Pt 1):1741–61.

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

CBS (2012). HSMR 2011, Methodological report. Statistics Netherlands, The Hague/Heerlen. http://www.cbs.nl/NR/rdonlyres/E7EC3032-B244-4566-947D-543B8AAE6E4A/0/2012hsmr2011methoderapport.pdf

Chong, C.A.K.Y., Nguyen G.C. and M.E. Wilcox (2012). Trends in Canadian hospital standardised mortality ratios and palliative care coding 2004-2010: a retrospective database analyses.. BMJ Open 2012;2:e001729. doi:10.1136/bmjopen-2012-001729.

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.

NHS - The Health and Social Care Information Centre (2013). The use of palliative care coding in the Summary Hospital-level Mortality Indicator.http://www.hscic.gov.uk/media/11150/Palliative-Care-Coding-report/pdf/Palliative_Care_Coding_Report.pdf

Ploemacher, J, A.Z. Israëls, D.J. van der Laan en A. de Bruin (2013). Gestandaardiseerde ziekenhuissterfte daalt in de tijd. Ned Tijdschr Geneeskd. 157 (22), 1034-1039.

Pouw, M.E., Peelen, L.M., Moons, K.G.M., Kalkman, C.J. and H.F. Lingsma (2013). Including post-discharge mortality in the calculation of hospital standardised mortality ratios: a retrospective analysis of hospital episode statistics. BMJ, in press.

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 der Laan, D.J. (2013). Quality of the Dutch Medical Registration (LMR) for the calculation of the Hospital Standardised Mortality Ratio. Statistics Netherlands, The Hague/Heerlen. http://www.cbs.nl/NR/rdonlyres/6290A0A8-4CC9-4DBF-AF0B-A3C6742EEA89/0/201308x10pub.pdf.

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.

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, a few hospitals started coding diagnoses in ICD10. In 2012, 38 hospitals (out of 84 in the HSMR model) were already coding all or part of the diagnoses in ICD10, the remaining hospitals still coded in ICD9-CM. We converted these ICD10 codes to their ICD9-CM equivalents and used the converted codes for the (H)SMR 2010-2012 and (H)SMR 2012. For the conversion of the ICD10 codes we used the conversion table 'ICD-10 – CvZ80', see http://www.rivm.nl/who-fic/ICD.htm.

Compared to the previous model (CBS, 2012), two minor changes were applied to the covariates: the categorisation of Source of admission was changed, and one (converted) ICD10 code was not allocated to a comorbidity group. Details are described in this appendix.

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 years 2011 and 2012 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" was 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 was 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], which had collected SES data for 2006 and 2010 and performed principal component analyses on variables concerning Income, Employment and Education level. Each four-letter postal area was thus assigned a component score.

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

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 collapsing was necessary. For 2009 and 2010, admissions followed the SES classification of 2006, whereas admissions of 2011 and 2012 followed the SES classification for 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 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 2005-2010 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. This classification was also used for the (H)SMR 2008-2010 and the (H)SMR 2009-2011.

To diminish their effect on the SMRs, ICD9-CM codes that have admissions in fewer than five different hospitals were placed in the category "others", as suggested by Van den Bosch. This is actually a category of admissions with ICD9-CM codes for which mortality rates are unreliable.

Just as for the other covariates, categories were collapsed with nearby categories if the number of admissions is smaller than 50 or if there are no deaths. The category "others", however, does not have a natural nearby category. We decided to collapse "others" 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 "others" equal to that of the category with which "others" is collapsed.

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 as 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 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. Secondary diagnoses registered as a complication arising during the hospital stay are not counted as a comorbidity either.

As mentioned earlier, diagnoses registered in ICD10 codes are first converted to ICD9-CM and then classified in the Charlson comorbidity groups. For the year 2012, however, it was decided not to include ICD10 code Z95.5 in comorbidity group 3 (peripheral vascular disease), as after converting to ICD9 this code would end up in this comorbidity group, while this (coronary) diagnosis does not belong here.

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. In former years a distinction was made between 'general hospitals' and 'academic or top-clinical hospitals', but this distinction has now been abandoned in preparation for the transition of the LMR to a new registration model in 2013/2014. In this model the distinction between 'general hospitals' and 'academic or top-clinical hospitals' can no longer be made. We therefore decided to combine these two categories for all admissions in 2009-2012. The impact of this combination on the HSMRs was minor.

Year of discharge: *2009, 2010, 2011. 2012*.

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 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 LMR

1. Hospitals with fewer than six completely registered months in a year (for inpatient admissions) are excluded. In 2010 hospitals were excluded if they had an LMR response rate of less than 50% 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).
3. ≤30% of inpatient admissions are coded as acute (not planned).
4. ≤0.5 secondary diagnoses are registered per inpatient admission, on average per hospital.[5]

Case mix

Hospitals are excluded if:

5. Expected mortality is 50 or less, i.e. $E_{dh} \leq 50$.
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 2012, and Table A2.2 for 2010-2012. (H)SMRs for 2010-2012 are only calculated if hospitals fulfil the criteria in 2012 and in the three-year period as a whole, and responded in all three years.

[5] 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, 2012

No.	Criterion	Authorization	No authorization	Total hospitals
0	No inpatient admissions	1	0	1
1	No/partial participation LMR	8	3	11
	of which no participation	*8*	*3*	*11*
	of which partial response (<6 months complete registration)	*0*	*0*	*0*
2	≥2% vague diagnosis code	0	0	0
3	≤30% admissions coded as acute	1	0	1
4	≤ 0.5 secondary diagnoses per inpatient admission (average per hospital)	1	0	1
5	≤50 expected mortality	1	0	1
6	≤ 70% hospital deaths within the 50 diagnosis groups considered	0	0	0
	Does not fulfil >1 of above-mentioned exclusion criteria (1-6)	2	1	3
	Meet all criteria	77[a)]	1	78
	Total hospitals	91	5	96

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

From Table A2.1 it can be concluded that 77 hospitals met all criteria in 2012 and had granted authorisation. For the period 2010-2012 this is the case for 69 hospitals (see Table A2.2). So HSMR 2012 figures were produced for 77 hospitals, and HSMR 2010-2012 figures for 69 hospitals.

Table A2.2. Number of hospitals according to exclusion criteria, 2010-2012

No.	Criterion	Authorization	No authorization	Total hospitals
0	No inpatient admissions	1	0	1
1	No/partial participation LMR	12	3	15
	of which no participation in one or more years	*11*	*3*	*14*
	of which partial response (<6 months) in one or more years	*1*	*0*	*1*
2	≥2% vague diagnosis code	0	0	0
3	≤30% admissions coded as acute	1	0	1
4	≤ 0,5 secondary diagnoses per inpatient admission (average per hospital)	1	0	1
5	≤50 expected mortality	1	0	1
6	≤ 70% hospital deaths within the 50 diagnosis groups considered	2	0	2
	Does not fulfil >1 of above-mentioned exclusion criteria (1-6)	4	1	5
	Meet all criteria	69[a)]	1	70
	Total hospitals	91	5	96

a) For one hospital (H)SMRs were calculated even though the percentage of deaths in the 50 diagnosis groups was slightly lower than 70% in 2010-2012. For another 2 hospitals (H)SMRs 2010-2012 were calculated even though 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; "-"=variable dropped because of < 50 admissions or no deaths)

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	0	1	0	1	1	1	1	1	1	0	1	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	0	-	1	-	1	1	0
13	1	0	0	0	1	1	1	1	1	-	1	-	0	-	0	-	-	1	0	-	1	-	0	1	0
14	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	0	-	1	1	-	1	-	1	1	1
15	1	1	0	0	1	1	1	1	1	0	0	0	-	-	0	-	-	1	0	-	1	-	1	1	0
17	1	0	0	1	1	1	1	1	1	-	1	-	-	-	1	-	-	1	0	-	1	-	0	1	0
19	1	1	1	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	-	1	1	0
29	1	-	0	1	1	1	1	0	1	0	1	-	-	-	0	-	-	1	0	-	1	-	0	1	0
32	1	0	0	1	1	1	1	0	1	1	1	-	-	-	1	0	-	1	1	-	1	-	0	1	0
38	1	0	0	1	1	1	1	0	1	-	1	0	-	-	0	-	1	1	1	0	1	-	1	0	1
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	1	0	0	0	1	0	-	1	1	1	1	1
44	1	0	0	1	1	1	1	0	1	0	1	0	-	-	0	-	0	1	1	-	1	-	0	1	0
50	1	0	0	1	1	1	1	1	1	0	1	0	-	1	0	0	0	1	1	-	1	-	0	1	0
55	1	1	0	1	0	0	1	0	0	1	1	0	-	1	0	0	0	0	1	-	1	-	0	1	1
59	1	0	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	1	1	-	1	0	1	1	0
85	1	0	0	1	1	0	1	0	1	0	1	-	-	-	0	-	-	1	1	-	1	-	0	1	0
96	1	0	1	1	1	1	1	1	1	1	0	0	-	-	0	0	0	1	0	-	0	-	1	1	0
100	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	-	1	-	1	1	0
101	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	-	1	-	1	1	0
103	1	0	0	1	1	1	1	0	1	1	1	0	-	1	0	0	-	1	1	-	1	-	1	1	1
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	1	1	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	1
109	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	-	1	-	1	1	1
114	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	-	1	-	1	1	1
115	1	1	0	1	1	1	1	1	1	1	1	0	0	-	0	-	1	1	1	-	1	-	0	1	0
116	1	1	0	1	1	1	1	1	1	1	1	0	-	-	1	1	0	1	1	-	1	-	1	1	1
117	1	0	0	1	1	0	1	1	1	0	0	0	-	1	0	0	-	1	1	-	1	-	1	1	0
122	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1	1	1	1	1
127	1	1	0	1	1	1	1	1	1	1	1	0	0	1	1	0	0	1	1	-	1	-	1	1	1
129	1	0	0	-	0	1	1	1	0	0	1	0	-	-	1	-	0	0	1	-	1	-	0	0	0
130	1	0	0	1	1	0	1	0	1	0	1	1	-	1	0	0	-	1	1	-	1	-	1	1	0
133	1	1	0	1	1	0	1	1	1	1	1	1	-	1	1	0	1	1	1	-	1	-	1	1	1
145	1	0	0	1	0	1	1	1	1	1	1	1	-	1	1	0	1	1	1	-	1	-	0	1	0
146	1	0	0	1	1	1	1	1	0	1	1	1	-	-	0	0	-	1	1	-	1	-	1	1	0
149	1	0	0	1	1	1	1	0	1	1	1	0	1	1	1	1	0	1	1	-	1	1	0	1	0
150	0	0	0	1	1	1	1	-	-	-	1	-	0	0	0	-	-	1	1	-	-	1	1	0	0
151	1	0	0	1	1	0	1	1	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	0	1	1	-	1	1	1	1	0
155	1	0	0	1	1	0	1	1	0	1	0	0	0	1	0	0	0	1	1	-	1	-	0	1	0
157	1	0	1	0	1	1	1	1	0	0	0	0	0	1	0	0	-	1	1	-	1	-	1	1	1
158	1	1	0	1	1	1	1	1	1	1	0	0	-	0	0	0	-	0	1	-	1	-	1	1	0
159	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	-	1	-	1	1	1
226	1	1	0	0	0	1	1	1	1	1	1	0	1	1	0	1	0	1	1	-	1	-	0	1	0
233	1	1	0	1	1	1	1	0	1	0	1	0	-	1	0	0	1	1	1	-	1	-	1	1	1
237	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	-	1	-	1	1	1
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	0	-	-	1	1	-	1	-	0	1	0
Total	48	19	13	42	43	40	48	34	43	27	43	8	17	31	16	7	9	47	42	0	47	8	35	47	20

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	969	28	6	1019	0	25	88	40	16	8	27	1	8	82	4	0	1	59	97	-	101	8	24	13	28
12	19	0	5	0	311	5	21	3	16	-	4	1	-	10	2	-	-	9	0	-	87	-	14	16	4
13	85	1	9	0	324	15	7	6	20	-	8	-	0	-	1	-	-	27	1	-	90	-	2	17	3
14	469	19	11	29	682	44	116	9	24	1	18	1	19	71	1	3	-	59	12	-	265	-	12	58	11
15	135	7	4	4	282	13	37	6	12	1	3	0	-	-	2	-	-	32	0	-	70	-	18	8	2
17	47	1	4	10	238	12	41	8	15	-	6	-	-	-	8	-	-	30	0	-	91	-	2	28	5
19	146	12	11	87	3689	21	125	17	54	4	52	2	17	43	0	0	1	65	13	-	281	-	86	74	15
24	25	0	4	24	924	2	2	1	5	0	2	0	-	-	0	-	-	19	0	-	201	-	8	14	2
29	58	-	3	5	218	9	22	0	8	2	5	-	-	-	0	-	-	34	0	-	192	-	2	26	2
32	37	1	2	32	626	12	47	0	6	7	5	-	-	-	12	2	-	42	7	-	258	-	4	21	4
38	121	0	8	39	456	15	52	2	7	-	5	2	-	-	0	-	7	107	33	1	28	-	96	7	16
39	307	3	14	87	261	8	38	1	53	-	5	3	-	-	1	-	-	36	11	-	3	-	38	14	1
42	206	1	20	88	1800	16	156	25	52	0	18	2	14	9	1	0	1	89	0	-	339	38	25	60	13
44	55	1	2	36	120	6	26	2	16	2	7	1	-	-	0	-	0	9	5	-	11	-	6	30	4
50	205	0	3	123	44	41	121	32	5	3	7	0	-	30	0	0	0	56	14	-	8	-	4	32	10
55	342	16	8	506	0	2	96	1	1	6	5	2	-	16	0	0	2	1	14	-	37	-	3	17	12
59	77	2	1	128	83	3	136	1	11	2	5	1	3	1	0	2	1	11	11	-	36	0	21	13	5
85	88	0	2	401	14	2	18	2	6	4	11	-	-	-	0	-	-	6	4	-	16	-	2	14	10
96	247	0	14	189	109	29	126	15	44	4	4	3	-	-	0	3	2	93	2	-	1	-	50	61	6
100	1588	1	28	614	18	17	581	24	116	8	34	0	4	79	7	15	13	105	68	-	26	-	43	95	6
101	622	0	6	112	81	9	333	12	62	13	28	0	34	21	7	8	0	122	20	-	21	-	127	61	5
103	329	1	3	95	20	27	128	0	88	23	16	0	-	15	0	3	-	29	25	-	76	-	41	32	14
106	758	16	29	803	72	1	277	8	42	14	82	0	25	20	15	24	4	75	44	-	53	-	33	90	15
107	248	0	10	750	149	12	3	14	9	4	60	-	-	-	23	-	-	15	14	-	4	-	68	26	16
108	1371	27	16	-	112	47	16	50	186	45	108	15	31	32	0	2	3	520	56	-	88	9	64	178	67
109	2373	2	13	7592	40	107	556	13	19	36	71	1	7	27	8	1	22	60	166	-	87	-	36	119	21

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	389	5	3	1127	444	45	170	37	25	5	20	3	9	5	4	0	0	76	21	-	16	-	29	47	17
115	692	23	7	1621	387	7	36	5	10	9	27	0	2	-	1	-	9	37	4	-	17	-	0	25	7
116	177	4	3	196	344	14	94	27	26	10	15	3	-	-	9	5	0	56	17	-	11	-	7	27	14
117	133	1	7	268	21	1	43	36	6	3	0	0	-	52	1	4	-	31	14	-	35	-	23	13	11
122	3317	37	17	161	0	133	651	37	154	68	18	12	18	130	3	0	17	183	415	0	268	14	72	170	31
127	504	7	8	83	114	19	325	22	17	7	15	0	2	18	13	1	0	88	33	-	22	-	54	40	53
129	196	0	3	-	1	4	22	5	1	0	4	1	-	-	6	-	3	0	14	-	19	-	3	6	6
130	342	0	4	46	72	0	13	0	6	3	28	5	-	24	4	0	-	27	10	-	76	-	32	40	11
133	921	16	7	1183	632	2	221	9	18	16	104	9	-	103	5	2	6	50	244	-	150	-	147	64	26
145	1105	1	2	265	2	8	98	21	16	15	90	6	-	36	6	2	6	74	42	-	89	-	1	48	5
146	346	0	1	142	26	17	91	10	3	8	21	12	-	-	2	0	-	38	34	-	40	-	8	10	9
149	562	3	5	205	21	13	143	3	33	7	13	3	12	12	7	20	2	99	12	-	58	13	1	24	7
150	6	0	2	30	85	6	14	-	-	-	6	-	2	3	0	-	-	29	9	-	-	125	13	5	3
151	150	0	1	539	85	1	30	10	6	1	8	8	1	10	0	1	-	80	13	-	49	56	64	17	3
153	320	8	5	324	12	4	171	11	39	7	18	0	2	78	1	1	1	56	62	-	63	7	23	46	10
155	295	0	6	1342	39	2	30	11	2	6	4	1	1	13	0	3	1	22	21	-	54	-	5	11	2
157	395	0	13	0	53	16	104	7	3	1	4	3	0	30	0	1	-	10	5	-	52	-	23	33	23
158	234	14	4	7	232	16	61	15	8	9	3	0	-	0	2	0	-	1	4	-	9	-	44	15	3
159	623	7	7	76	19	9	185	13	42	7	14	0	20	37	16	5	1	51	10	-	63	-	18	51	18
226	789	234	2	3	2	120	750	9	62	20	89	0	35	120	3	14	1	156	19	-	38	-	0	85	6
233	532	26	7	2731	4	7	64	2	10	3	6	2	-	15	1	2	4	11	4	-	12	-	11	11	11
237	384	17	3	309	155	27	195	23	27	11	64	6	31	70	1	0	1	48	15	-	21	-	75	24	12
238	571	1	16	495	12	19	122	12	21	12	33	0	15	37	12	3	5	87	49	-	35	-	207	36	9
249	235	3	3	-	2	18	11	1	0	-	7	-	6	22	3	-	-	4	17	-	27	-	2	12	5
Total	24145	548	373	23922	13439	1009	6812	615	1423	415	1207	11	319	1270	19	12	11	3024	1705	1	3696	270	1688	1984	600

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	2	3	5
12	11	1	4	1	1	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	12	1	4	2	1	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	-	1	-	2	3	5
19	13	1	5	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	2	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	-	1	3	5
32	11	1	4	2	1	1	1	1	1	1	1	-	-	-	1	1	-	1	1	-	1	-	2	3	5
38	17	1	4	5	1	1	1	1	1	-	1	1	-	-	1	-	1	1	1	1	1	-	2	3	5
39	19	1	5	6	1	1	1	1	1	-	1	1	-	-	1	-	-	1	1	-	1	-	2	3	5
42	18	1	5	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	2	3	5
44	17	1	4	3	1	1	1	1	1	1	1	1	-	-	1	-	1	1	1	-	1	-	2	3	5
50	14	1	5	4	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	2	3	5
55	16	1	4	3	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	2	3	5
59	18	1	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	2	3	5
85	19	1	4	1	1	1	1	1	1	1	1	-	-	-	1	-	-	1	1	-	1	-	2	3	5
96	15	1	4	3	1	1	1	1	1	1	1	1	-	-	1	1	1	1	1	-	1	-	2	3	5
100	15	1	5	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	2	3	5
101	13	1	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	2	3	5
103	18	1	4	3	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	2	3	5
106	19	1	5	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	2	3	5
107	16	1	4	2	1	1	1	1	1	1	1	-	-	-	1	-	-	1	1	-	1	-	2	3	5
108	17	1	5	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	2	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	-	2	3	5
114	16	1	5	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	2	3	5
115	13	1	4	5	1	1	1	1	1	1	1	1	1	-	1	-	1	1	1	-	1	-	2	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	5	4	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	2	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	2	3	5
127	14	1	5	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	2	3	5
129	18	1	4	-	1	1	1	1	1	1	1	1	-	-	1	-	1	1	1	-	1	-	2	3	5
130	17	1	4	3	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	2	3	5
133	20	1	5	5	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	2	3	5
145	18	1	5	3	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	2	3	5
146	11	1	4	2	1	1	1	1	1	1	1	1	-	-	1	1	-	1	1	-	1	-	2	3	5
149	13	1	4	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	2	3	5
150	10	1	4	1	1	1	1	-	-	-	1	-	1	1	1	-	-	1	1	-	-	1	2	3	5
151	17	1	4	6	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	-	1	1	2	3	5
153	13	1	5	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	2	3	5
155	16	1	4	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	2	3	5
157	18	1	4	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	-	1	-	2	3	5
158	14	1	4	1	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	2	3	5
159	15	1	5	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	2	3	5
226	10	1	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	2	3	5
233	20	1	5	8	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	2	3	5
237	18	1	5	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	2	3	5
238	20	1	4	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	2	3	5
249	13	1	4	-	1	1	1	1	1	-	1	-	1	1	1	-	-	1	1	-	1	-	2	3	5
Total	772	49	220	144	50	50	50	49	49	43	50	42	26	34	50	35	30	50	50	2	49	9	98	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 2012.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.