Statistics Netherlands

Statistics Methods

HSMR 2013: Methodological report

2014 | 47

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1. Introduction

Just as for the last three years (see CBS, 2011; 2012 and 2013), Statistics Netherlands (CBS) has calculated the Hospital Standardised Mortality Ratios (HSMRs) for Dutch hospitals for the period 2011-2013. 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. The model as such has not changed compared to the previous year, but as most hospitals adopted ICD10 coding in 2013, diagnosis groups and comorbidities are now derived directly from the ICD10 codes without a translation to ICD9-CM. Section 3.4 describes the effects of this.

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

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

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

1.1 What is the (H)SMR?

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

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

The numerator is the *observed* number of deaths with main diagnosis *d* in hospital *h*. The denominator is the *expected* number of deaths for this type of admission under the assumption that individual mortality probabilities (per admission) do *not* depend on the hospital, i.e. are equal to mortality probabilities of identical cases in other hospitals. The denominator is therefore founded on a model based on data from all hospitals, in which the mortality of an admission is explained by characteristics of the patient, such as age, and characteristics of the admission, such as diagnosis and whether the admission is acute and unplanned versus planned. Characteristics of the hospital, such as the number of doctors per bed, are generally not incorporated in the model, since these can be related to the quality of care in the hospitals, which is the intended outcome of the indicator. The model thus produces an expected

(estimated) mortality probability for each admission. Adding up these probabilities per hospital gives the total expected mortality over all admissions of that hospital. For each diagnosis *d*, the average SMR_d across the hospitals equals 100 when each hospital is weighted with its (relative) expected mortality. Not all diagnoses are included in the calculation, only 50 "diagnosis groups *d*" that account for about 80% of entire hospital mortality. Day admissions are also excluded.

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

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

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

1.3 History of the HSMR

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

In 2005, Jarman started to calculate the (H)SMR for the Netherlands. Later on, these Dutch (H)SMRs were calculated by Kiwa Prismant, in collaboration with Jarman and his colleagues of Imperial College London, Dr Foster Intelligence in London and De Praktijk Index in the Netherlands. Their method is described in Jarman et al. (2010) and was slightly adapted by Kiwa

[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.

Prismant (Prismant, 2008) up to reporting year 2009. In 2010 Dutch Hospital Data (DHD, Utrecht), the holder of the national hospital discharge data, asked CBS to calculate the (H)SMRs for the period 2008-2010 and for subsequent years. CBS is an independent public body and familiar with the input data for the HSMR, i.e. the hospital discharge register (LMR: Landelijke Medische Registratie, and its successor LBZ: Landelijke Basisregistratie Ziekenhuiszorg), as it uses this data source for a number of health statistics (see www.statline.cbs.nl).

The starting point for CBS was the HSMR methods previously used by Kiwa Prismant. As a result of progressive insight CBS introduced some changes in the model for the HSMR 2008-2010 (CBS, 2011), in close collaboration with, and largely based on the extensive research by the Dutch scientific HSMR Expert group set up by the hospital associations. With the exception of the first year that CBS produced the HSMR (2008-2010), the model has not undergone much change. In 2013, the only change is the switch by most hospitals to using ICD10. Diagnosis groups and comorbidities have therefore been derived directly from the ICD10 codes. For comorbidities, a new set of ICD10 definitions was used, which were determined after a literature review of the available ICD10 translations of the Charlson comorbidities.

1.4 Confidentiality

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

1.5 CBS output

CBS estimated the models for expected mortality per diagnosis for 2011-2013. 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/LBZ 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/LBZ data were not too deviant in some respects (see Appendix 2).

CBS produces the following output:

1. A hospital-specific report for each hospital, sent via DHD, containing the HSMR and the diagnosis-specific SMR figures for 2011-2013 and the individual years. SMRs are also presented for different patient groups (by age, sex and urgency of admission) and diagnosis clusters. Hospitals can see how they compare with the national average, overall, and per diagnosis and patient group. CBS only made reports for hospitals not excluded under the exclusion criteria and that signed the authorisation request.
2. Each hospital not excluded on the grounds of the exclusion criteria and that signed the authorisation request is provided with a dataset with the mortality probabilities for all its admissions. Besides the probability, each record contains the observed mortality (0 or 1)

and the scores on the covariates of the HSMR model. The hospital can use these data for internal investigation.

3. A report on the methods used for calculating the HSMR for 2011-20132 and separate years, including the model results and parameters (this document; see www.cbs.nl).

1.6 Limitations of the HSMR

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

- Data quality is not uniform across hospitals. Van der Laan (2013) studied the impact of differences in the registration of the Charlson comorbidities and the urgency of the admission on the HSMR 2010. Differences between hospitals in the average number of registered Charlson comorbidities per admission are very large, even when adjusted for covariates like severity of the main diagnosis. It seems that a considerable part of these differences is due to variation in coding practice between hospitals. This harms the comparability of the HSMRs as the higher the number of comorbidities, the lower the HSMR. We observe an increase in the registration of Charlson comorbidities in the last few years, but probably there still is a 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/LBZ and therefore cannot be included in the expected mortality model (denominator of the HSMR). So essential covariates are missing, and if the case mix differs too much between hospitals, standardisation cannot solve this problem completely.

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

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

In addition to the above-mentioned limitations, the comparison of the 2013 (H)SMR results with those of previous years is less straightforward, partly because of the transition to ICD10 by most hospitals in 2013 (see section 3.4):

- For the HSMR 2013, the main diagnosis groups are derived from the registered ICD10 codes instead of from the ICD9-CM codes. This caused changes in the number of admissions in some diagnosis groups.

- Because of a new registration rule imposed by the NZa, inpatient admissions without overnight stay can only be recorded as such if the patient dies on the same day or is transferred to another hospital. This caused a selective decrease in the admissions (mainly admissions without mortality) in 2013.

- For 2013, the Charlson comorbidities are derived directly from the registered ICD10 codes. The new ICD10 definitions of the comorbidities adopted caused a change in the frequency of some comorbidities in 2013.

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/LBZ as covariates. The regression models for the (H)SMR 2011-2013 and the (H)SMRs of the individual years use LMR/LBZ data for the last four years, i.e. the period 2010-2013. The addition of 2010 increases the stability and accuracy of the estimates, while keeping the model up to date. This procedure is identical to the one used for previous periods, when CBS also used models covering the most recent four-year period.

Compared to the previous year (CBS, 2013) there are no changes in the model itself. However, because in 2013 most hospitals coded diagnoses in ICD10 (instead of in ICD9-CM in previous years), the main diagnosis groups and the Charlson comorbidities are now derived directly from the registered ICD10 codes. Because of this, the results of 2013 are less comparable to previous years. Furthermore, because of a new coding rule of the Dutch Healthcare Authority (NZa) , there has been a selective decrease in the number of inpatient admissions (fewer one-day inpatient admissions, particularly those without mortality). This also makes the results of 2013 less comparable to previous years. Both effects are discussed in section 3.4. However, these effects do not hamper comparisons between hospitals *within* 2013, as the new registration practices apply to almost all hospitals. Only for the few hospitals that still coded in ICD9-CM in 2013 the results are less comparable. This was explained in the methodological report of last year (CBS, 2013).

The classification of the covariate 'severity of main diagnosis' is still based on ICD9-CM. More years of ICD10 coded hospital diagnoses are needed in the Netherlands before a new classification in ICD10 can be developed. Therefore the main diagnoses registered in ICD10 were converted to ICD9-CM to determine the severity covariate. On the other hand, for the few hospitals that registered in ICD9-CM in 2013, the diagnoses were converted to ICD10 to derive the main diagnosis groups and the Charlson comorbidities.[2]

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/LBZ. However, not all hospitals participate in the LMR/LBZ. Table 1 gives the response numbers for 2013.

In principle, the HSMR model includes all short-stay hospitals with inpatient admissions participating in the LMR/LBZ in 2010-2013. The target population thus includes all general, university and short-stay specialised hospitals with inpatient admissions. One of the 88 hospitals participating in the LMR/LBZ has day admissions only, and is therefore excluded from the model. Eight hospitals did not participate in the LMR/LBZ in 2013. The admissions of these hospitals cannot be analysed. Another 32 hospitals were partial non-respondents in 2013, in the sense that they only provided diagnosis information on part of their inpatient admissions. For

[2] For the conversion tables used, see www.rivm.nl/who-fic/ICD.htm

the partial non-respondents only the completely registered LMR/LBZ admissions are included in the HSMR model (with exceptions for some hospitals, see below). In total, the number of hospitals included in the HSMR model was 87 in 2013, 84 in 2012, 86 in 2011 and 83 in 2010.

Table 1. Participation of hospitals in the LMR/LBZ 2013

Type of hospital	Total hospital population	LMR/LBZ population	Total hospitals participating in LMR/LBZ	Participating hospitals with partial response
General hospitals	84	84	78	26
University hospitals	8	8	8	5
Specialised hospitals	8[a)]	4[b)]	2	1
Total hospitals	100	96	88	32

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.

For a number of partially non-responding hospitals only the fully registered months were included in the model, as in the other months there were indications that fatal cases were registered completely and non-fatal cases partially. The partially registered months of these hospitals were removed from the model as these would otherwise unjustly influence the estimates. For the years 2010 to 2013 this was done for 2, 1, 4 and 6 hospitals, respectively.

All the above-mentioned hospitals were included in the model, but (H)SMRs were only calculated for hospitals that met the criteria for LMR/LBZ 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 2013 population of hospital stays comprises all inpatient admissions that ended in 2013. 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 80.8% of entire inpatient hospital mortality and 36.5% of inpatient admissions in 2011-2013. Moreover, some registered admissions of a number of partially non-responding hospitals were excluded because of over-reporting of fatal cases (see section 2.1.1).

Lastly, admissions of foreigners are excluded from the HSMR model, partly in the context of possible future modifications of the model, when other data can be linked to admissions of

Dutch residents. The number of admissions of foreigners is relatively small (28,801 inpatient admissions in 2010-2013).

Altogether, we included in the 2010-2013 model 2,393,011 inpatient admissions registered in the LMR/LBZ 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 2,393,011 inpatient admissions mentioned in section 2.1 is 4.2%. But, of course, rates are different for different diseases.

2.3 Stratification

Instead of performing one logistic regression for all admissions, we performed a separate logistic regression for each of the selected diagnosis groups *d*. These sub-populations of admissions are more homogeneous than the entire population. Hence, this stratification may improve the precision of the estimated mortality probabilities. As a result of the stratification, covariates are allowed to have different regression coefficients across diagnosis groups.
The diagnosis groups are clusters of ICD codes registered in the LMR/LBZ. 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 and ICD10 codes of these 50 CCS groups are available in a separate file published together with this report. The ICD9-CM definitions of the 50 CCS groups is used for the data up to 2012, and the ICD10 definitions is used for the 2013 data. The 50 CCS diagnosis groups have been kept constant over the last few years. Although the real "top 50" of CCS groups with highest mortality has changed slightly in the course of the years, for reasons of continuity CBS decided to use the same groups as Kiwa Prismant had. So the model includes 50 separate logistic regressions, one for each CCS diagnosis group *d* selected.

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

By including covariates of patient and admission characteristics in the model, the in-hospital mortality is adjusted for these characteristics. As a result, the (H)SMRs are adjusted for these covariates as well. Thus, variables (available in the LMR/LBZ) 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/LBZ 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

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

Social Research (SCP). For 2011 and later updated data from SCP were used for the SES scores per postal code.
- Severity of main diagnosis (9 categories). Instead of CCS diagnosis subgroups, we used a classification of severity of the main diagnosis in terms of mortality rates, as suggested by Van den Bosch et al. (2011); see Appendix 1.
- Urgency of admission (elective, acute);
- Comorbidity_1 – Comorbidity_17, i.e. a separate dummy variable (indicator variable) for each of the 17 comorbidity groups that make up the "Charlson index". The groups are listed in Table A1.1 in Appendix 1. Up to 2012 the ICD9-CM definitions of the Charlson comorbidities were used. For 2013 CBS used a new set of ICD10-definitions, which were determined after a literature review of the available ICD10 translations. Each dummy variable indicates whether the patient suffers from the specific comorbidity (e.g. diabetes), based on the secondary diagnoses registered in the LMR/LBZ. 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; see Appendix 1.
- Year of discharge (4 categories: 2010-2013);
- Month of admission (6 categories of two months).

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

2.5 Computation of the model and the (H)SMR

2.5.1 SMR and HSMR

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

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

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

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

and

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

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

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

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

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

It follows from the above formulae that:

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

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

2.5.2 Modelling and model-diagnostics

We estimated a logistic regression model for each of the 50 CCS diagnosis groups, using the categorical covariates mentioned in section 2.4 and in Appendix 1. The latter also gives an overview of their categories. Categories, including the reference category, are collapsed if the number of admissions is smaller than 50, to prevent standard errors of the regression coefficients becoming too large. This collapsing is performed starting with the smallest category, which is combined with the smallest nearby category, etc. For variables with only two categories collapsing results in dropping the covariate out of the model (except for comorbidities 17 (Severe liver disease) and 11 (Diabetes complications) which are first combined with comorbidity 9 (Liver disease), and comorbidity 10 (Diabetes), respectively; see Appendix 1). For technical reasons connected with the chosen R-software, collapsing also took place when there were no deaths in the category. All regression coefficients are presented in the file "Coefficients HSMR 2013.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 2013.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

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

where $\mathrm{HSMR}_h^{-x_j}$ is the HSMR that would result from deletion of covariate x_j, and N=81 the total number of hospitals for which an HSMR was calculated for 2013.

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.

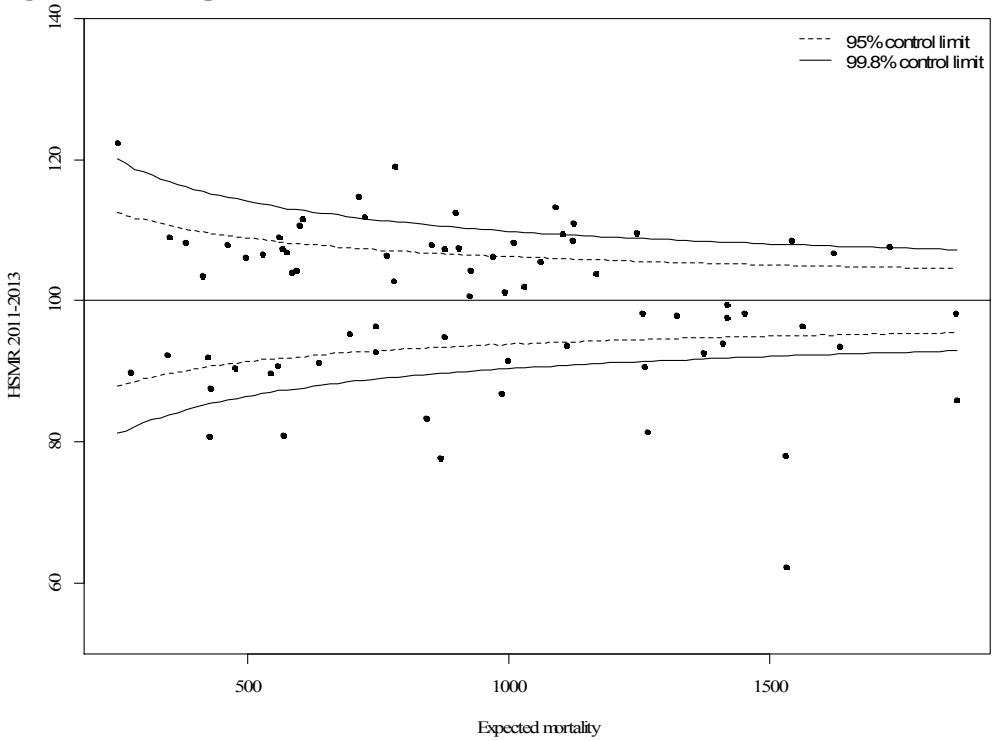
2.5.3 Confidence intervals and control limits

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 2011-2013, 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 2011-2013 it is 98.9 (n=73 hospitals). For the year 2013 the average HSMR of the non-excluded hospitals (n=81) is 99.4. 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 2011-2013



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. 2010-2012 and 2011-2013) 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 2013 not presented here). Observed mortality (numerator) and expected mortality (denominator) are then calculated for the 2013 admissions, whereas the expected mortality model of the HSMR still uses the 2010-2013 data. If a hospital has a significantly high HSMR in 2013, but not for 2011-2013, 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 2011-2013, but not in 2013, this does not necessarily mean that the situation improved in 2013, as the one-year figures are less often significant because of the larger margins. In such cases, not only the significance should be taken into account, but also the HSMR levels over the years.

3. Model results and evaluation

This chapter presents and evaluates the model results. Some summary measures of the 50 logistic regressions are presented, one for each CCS group, with inpatient mortality as the dependent variable and the variables mentioned in section 2.4 as explanatory variables. More detailed results are presented in Appendix 3, and the regression coefficients and their standard errors in the file "Coefficients HSMR 2013.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, severity of the main diagnosis, urgency of the admission 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. The first eight covariates in table 2 are the same as previous year. Comorbidity 15, HIV, was not significant for any of the CCS groups. It was seldom registered as a comorbidity; most CCS groups had fewer than 50 admissions with HIV comorbidity. In general the number of significant parameters for the comorbidities seems to have increased. This is probably caused by the general increase in comorbidity coding (this was also seen previous year; see CBS, 2013), and by the new definitions for the comorbidities adopted in 2013 (see section 3.4).

Table 2. Statistical significance of the covariates for the 50 logistic regressions (summary), HSMR 2013 model

Covariate	No. of significant results	Covariate	No. of significant results
Comorbidity_2	49	Source of admission	32
Age	48	Comorbidity_5	27
Comorbidity_13	46	Comorbidity_10	24
Comorbidity_16	45	Sex	19
Severity main diagnosis	44	Comorbidity_8	18
Comorbidity_4	43	Month of admission	16
Comorbidity_6	43	Comorbidity_17	14
Urgency	42	SES	12
Comorbidity_9	42	Comorbidity_11	11
Comorbidity_14	41	Comorbidity_12	11
Year of discharge	40	Comorbidity_7	9
Comorbidity_1	38	Comorbidity_15	0
Comorbidity_3	34		

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 severity of main diagnosis has the highest explanatory power, with 22,713 as the sum of the Wald statistics. Age and urgency of admission are also important variables. The explanatory powers of Month of admission, Sex and SES are relatively small. This is also true for some comorbidity groups. 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 22,419 with 698 df, but because of interference of comorbidities this is only an indication of their combined effect. In any case, it can be concluded that several comorbidity groups also make an important contribution to the model.

Table 3. Wald chi-square statistics for the 50 logistic regressions, HSMR 2013 model

Covariate	Sum of Wald statistics	Sum of df	Covariate	Sum of Wald statistics	Sum of df
Severity main diagnosis	22713	151	Comorbidity_1	936	50
			Comorbidity_3	725	50
Age	21475	758	Month of admission	589	250
Urgency	12346	50	Seks	520	49
Comorbidity_2	7235	50	Comorbidity_5	489	43
Comorbidity_16	3601	49	Comorbidity_17	443	15
Comorbidity_13	2702	50	SES	347	222
Year of discharge	1842	150	Comorbidity_10	272	50
Source of admission	1643	98	Comorbidity_8	233	26
Comorbidity_14	1500	50	Comorbidity_12	169	31
Comorbidity_9	1376	46	Comorbidity_11	143	41
Comorbidity_4	1251	49	Comorbidity_7	118	46
Comorbidity_6	1225	50	Comorbidity_15	1	2

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 2013, as measured by formula (3.1) for the 81 hospitals for which HSMRs are calculated. Age and Severity of the main diagnosis had the largest effect on mortality (for the years 2010-2013), but their impact on *hospital* mortality is smaller, apparently as a result of relatively small differences in their distributions between hospitals. Comorbidity discriminates much more between hospitals. This is caused by differences in case mixes, but possibly also by differences in coding practice. Notice that we consider the comorbidities as one group here. Deleting Sex has hardly any impact on the HSMRs. Compared to Sex, SES has a reasonable impact on the HSMR 2013. 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 2013 by inclusion/deletion of covariates

Covariate	Average shift in HSMR	Covariate	Average shift in HSMR
Comorbidity [a)]	8.24	SES	0.86
Age	4.70	Source of admission	0.76
Urgency	2.64	Month of admission	0.66
Severity main diagnosis	2.59	Sex	0.14

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 (2013). Only “Cancer of pancreas” and “Leukaemias” differ by more than 0.02 (0.022 and -0.020 respectively). Most of the values of the C-statistic lie between 0.7 and 0.9. The highest values are found for the CCS groups “Cancer of breast” (C=0.94), “Intracranial injury”, “Biliary tract disease” and “Other gastrointestinal disorders” (C=0.92), “Cancer of bladder”, “Cancer of prostate” and “Peripheral and visceral atherosclerosis” (C=0.91). For these seven CCS groups the covariates strongly reduce the uncertainty in predicting patient mortality. The lowest values are found for “Congestive heart failure; non-hypertensive” (C=0.67), “Aspiration pneumonitis; food/vomitus” (C=0.68), “Chronic obstructive pulmonary disease and bronchiectas” (C=0.71) and “Liver disease; alcohol-related” (C=0.72).

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)	19928	5123	0,76
12	Cancer of esophagus	9639	584	0,78
13	Cancer of stomach	13309	620	0,80
14	Cancer of colon	40920	1690	0,82
15	Cancer of rectum and anus	20887	593	0,81
17	Cancer of pancreas	11658	872	0,76
19	Cancer of bronchus; lung	72769	4843	0,84
24	Cancer of breast	53221	455	0,94
29	Cancer of prostate	22958	477	0,91
32	Cancer of bladder	41484	479	0,91
38	Non-Hodgkins lymphoma	19326	901	0,83
39	Leukaemias	19575	1159	0,81
42	Secondary malignancies	70932	4366	0,79
44	Neoplasms of unspecified nature or uncertain behaviour	16846	307	0,84
50	Diabetes mellitus with complications	29785	468	0,87
55	Fluid and electrolyte disorders	26932	865	0,83
59	Deficiency and other anaemia	45432	488	0,80
85	Coma; stupor; and brain damage	3979	529	0,82
96	Heart valve disorders	33618	1103	0,81
100	Acute myocardial infarction	94759	4739	0,79
101	Coronary atherosclerosis and other heart disease	187542	1321	0,82
103	Pulmonary heart disease	28614	1096	0,79
106	Cardiac dysrhythmias	182853	1255	0,87
107	Cardiac arrest and ventricular fibrillation	9356	3927	0,76
108	Congestive heart failure; nonhypertensive	99364	9444	0,67
109	Acute cerebrovascular disease	96879	11722	0,79
114	Peripheral and visceral atherosclerosis	36039	1651	0,91
115	Aortic; peripheral; and visceral artery aneurysms	26397	2585	0,89
116	Aortic and peripheral arterial embolism or thrombosis	27751	630	0,88
117	Other circulatory disease	23011	509	0,87
122	Pneumonia (except that caused by tuberculosis or sexually transmitted diseases)	124230	9843	0,78
127	Chronic obstructive pulmonary disease and bronchiectas	90122	3951	0,71
129	Aspiration pneumonitis; food/vomitus	5231	1308	0,68
130	Pleurisy; pneumothorax; pulmonary collapse	22665	725	0,84
133	Other lower respiratory disease	85559	3003	0,86
145	Intestinal obstruction without hernia	31534	1638	0,85
146	Diverticulosis and diverticulitis	35344	517	0,87
149	Biliary tract disease	125805	649	0,92
150	Liver disease; alcohol-related	5286	651	0,72
151	Other liver diseases	15824	972	0,83
153	Gastrointestinal haemorrhage	32937	1082	0,81
155	Other gastrointestinal disorders	49792	683	0,92
157	Acute and unspecified renal failure	13546	1058	0,76
158	Chronic renal failure	16200	573	0,86
159	Urinary tract infections	68916	1573	0,83
226	Fracture of neck of femur (hip)	64914	2340	0,80
233	Intracranial injury	55620	1679	0,92
237	Complication of device; implant or graft	83652	985	0,87
238	Complications of surgical procedures or medical care	77566	1055	0,87
249	Shock	2505	1139	0,73

3.3 Regression coefficients

The file "coefficients HSMR 2013.xls" contains the estimated regression coefficients (columns "Estimate"), also called "log-odds", for each of the 50 logistic regressions, as well as their standard errors (columns "Std. Err."). The estimated regression coefficients are the elements of the vector $\hat{\beta}_d$ in formula (2.4), for each diagnosis *d*. Notice that a β-coefficient has to be interpreted as the difference in log-odds between the category in question and the reference category (first category of the same covariate). For the sake of clarity, the reference categories are given in the first row of the corresponding covariates, and by definition have zero coefficient for each regression. In many cases categories are collapsed (see section 2.5.2). This results in equal coefficients for the collapsed categories. If all categories were collapsed into one category for a certain variable and for a certain CCS group (i.e. if there was only one category with ≥50 admissions and ≥1 death), the variable was dropped from the model and all associated coefficients are set to zero.

3.4 Effect of transition from ICD9-CM to ICD10

In 2012, 38 hospitals coded their diagnoses completely or partially in ICD10. The remaining hospitals still coded completely in ICD9-CM. For the HSMR figures for that year it was decided to convert all ICD10-codes to ICD9-CM (see CBS, 2013). However, in 2013 nearly all hospitals (80 of the 87 hospitals in the model) coded their diagnoses completely in ICD10. Since information is lost when converting from ICD10 to ICD9-CM, it was decided to no longer convert the ICD10 codes to ICD9-CM and to derive the CCS main diagnosis groups and comorbidities directly from the ICD10 codes. Only for the severity of the main diagnoses were ICD10 codes still first converted to ICD9-CM, as the severity classification is based on historical data (see appendix 1), and is therefore only available in ICD9-CM. More years of ICD10 coded hospital diagnoses are needed in the Netherlands before a new severity classification can be developed in ICD10.

Using the ICD10 codes directly to determine the CCS groups and comorbidities did, however, have some effects on the HSMR figures for 2013:

1. The number of admissions changed in some of the CCS groups. This is caused by the fact that the ICD10 code belonging to a specific admission is assigned to a different CCS group than the ICD9-CM code would have assigned to for the same admission. More details on this can be found in section 3.4.1 .
2. For the Charlson comorbidities different ICD10 translations are available in the literature. For each Charlson comorbidity CBS selected a ICD10 definition and tested the performance of the CBS list and other Charlson lists, see section 3.4.2.

3.4.1 Effect on the CCS groups

For 2013 the same 50 CCS groups have been used for the calculation of the HSMR as in previous years. However, when using the ICD10 definitions[4] about 15,000 fewer admissions are assigned to these 50 groups than if the ICD9-CM definitions had been used (of a total of nearly 560,000 admissions). This is mostly caused by CCS group 133 ("Other lower respiratory disease"). Using ICD10 definitions, this group has about 11,000 fewer admissions, which have mostly moved to other groups of respiratory diseases (CCS groups 125, 131 and 134) that are not in the 50 CCS groups selected for the HSMR. Thus, CCS group 133 has become much smaller in 2013 than in previous years. If - for a specific hospital – not only the size but also the patient case mix of this

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

group has changed, then the 2013 SMR for this diagnosis group will be less comparable to the SMR for previous years.

Differences between ICD9-CM and ICD10 definitions are to a lesser extent also visible in other CCS groups. For example, CSS groups 114 (“Peripheral and visceral atherosclerosis”), 155 (“Other gastrointestinal disorders”) and 159 (“Urinary tract infections”) also have fewer admissions using ICD10, while CCS groups 117 (“Other circulatory disease”) and 238 (”Complications of surgical precedures or medical care”) have more.

The net effect is that the percentage of admissions that fall within the 50 CCS groups included in the HSMR is smaller when ICD10 is used than when ICD9-CM is used (36.5 percent versus 37.5 percent in 2013). Also the percentage of deaths that fall within the 50 CCS groups (compared to total mortality in all admissions) is smaller: 79.4 percent versus 81.9 percent. The mortality rate in the 50 CCS groups remains practically the same (4.1 percent).

Furthermore, there was an overall decrease of 13 percent of the number of inpatient admissions registered in 2013 compared to 2011. This is primarily caused by a new coding rule of the Dutch Healthcare Authority (NZa) that forbids registering admissions without overnight stay as inpatient admissions, except when the patient dies on the same day or is transferred to another hospital. Because of this, the number of one-day inpatient admissions has dropped by 60 percent compared to 2011, and this particularly concerns admissions without death. Although the new registration rule already came into effect in 2012, implementation in the LMR/LBZ registration was only well visible in 2013. Since one-day inpatient admissions accounted for a significant part of the total number of admissions (15 percent in 2011), and as the drop concerns mostly admissions without death, the crude mortality rate has increased in 2013 for the first time in years. This is solely the effect of the new registration rule: if one-day admissions are left out of the calculations, the trend of a decreasing crude mortality rate continues.

The 13 percent decrease of inpatient admissions in 2013 also applies for the selection of 50 CCS groups of the HSMR if– for the sake of comparability – we use the ICD9-CM definitions of these CCS groups for both 2011 and 2013. Some CCS groups show a larger decrease in the number of admissions from 2011 to 2013, for example group 101 (“Coronary atherosclerosis and other heart disease”), 106 “Cardiac dysrhythmias”) and 133 (“Other lower respiratory disease). There are also some groups, for example group 127 (“COPD and bronchiectas”), where the number has risen. There may be several reasons for this. First, the decrease in registration of one-day admissions may affect one CCS group more than another. For CCS group 106 for instance, the reduced registration of one-day admissions fully explains the large decrease in the total number of admissions, while for other CCS groups also other factors play a part: for example there may have been a real decrease in the number of patients hospitalised. Also, the different coding systems used by the hospitals (ICD10/ICD9CM) combined with the default conversion from ICD10 to ICD9-CM used for this comparative study, may have resulted in differences. If a certain diagnosis is registered in ICD9-CM with a code that falls within CCS group A, for example, and the same diagnosis is registered in ICD10 with a code that - after default conversion - falls within CCS group B, then this complicates comparisons over time, even though the same ICD9-CM definitions of the CCS groups have been used for all years.

The change in the registration of one-day inpatient admissions in 2013 affects the comparability of the numbers of admissions and number of deaths between 2013 and earlier years. Because

the drop in registered admissions is selective (one-day admissions, and mainly those without mortality), the case mix of the patient population for which the (H)SMR is calculated has changed somewhat in 2013. Furthermore, the change from ICD9-CM to ICD10 also caused some changes in the number of admissions for which the (H)SMR is calculated (most notably CCS group 133). If the patient case mix has also changed for the diagnosis groups concerned, this also affects the comparability of the (H)SMRs to those of previous years.

However, these effects do not hamper comparisons between hospitals *within* 2013, as the new registration practices apply to almost all hospitals. Only for the few hospitals that still coded in ICD9-CM in 2013, will results be less comparable with other hospitals. This was explained in last year's methodological report (CBS, 2013).

3.4.2 ICD10-definition for comorbidities

Up to 2012, the ICD9-CM definitions of Deyo *et al.* (1992) were used to define the 17 Charlson comorbidities. However, several conversions to ICD10 are available. In a comparative study by Sundararajan *et al*. (2007) the conversions of Sundararajan *et al*. (2004) and Quan *et al*. (2005) performed best. The conversion by Quan *et al.* performed slightly better, but not significantly. The United Kingdom uses a different conversion in the Summary Hospital Mortality Index, which has not yet been described or validated in literature.
For the calculation of the HSMR 2013, CBS selected a different set of ICD10 Charlson comorbidity definitions, mostly derived from conversions available in literature. The CBS version is presented in appendix 1 (table A1.1). For most diagnosis groups (11 of the 17) the CBS version is identical or nearly identical to Quan *et al.* For seven comorbidity groups the CBS follows Sundararajan *et al*., and three of these groups are also identical to Quan *et al.* For two comorbidity groups, the diabetes groups 10 and 11 in table A1.1, a different choice was made: CBS only places codes ending in '9' (=without complication) in group 10 and the remaining codes in group 11. This resulted in a frequency increase in group 11 ('diabetes complications') and a decrease in group 10 ('diabetes'). However, group 10 is still by far the largest of the two.

Like the version of Quan *et al.,* in general the CBS version contains more ICD10 codes per comorbidity group than the version of Sundararajan *et al.*, and also more than the original ICD9-CM version of Deyo *et al.* used for the calculation of the HSMR in previous years. As a result, comorbidities congestive heart failure, peripheral vascular disease, dementia, (severe) liver disease and renal disease in particular have higher frequencies in 2013 than in previous years. As a result, the average number of Charlson comorbidities per admission shows a larger increase in 2013 than in the previous years (see table 6). But the overall number of comorbidities registered has also increased in 2013 (by 18 percent). Therefore, the increase in the number of Charlson comorbidities in 2013 (by 28 percent) is caused both by an overall increase in comorbidity coding (as in the previous years) and by a change to the new ICD10 definition of the comorbidities.

The increase in the number of registered comorbidities per admission does not affect the comparability of the (H)SMR results between hospitals within 2013 as the same ICD10 definition is used for all hospitals. For the few hospitals that still use ICD9-CM, the codes are first converted to ICD10.

Table 6. Registered comorbidities per inpatient admission, 2009-2013

	2009	2010	2011	2012	2013	Increase 2012-2013
Number of comorbidities per admission	1.15	1.30	1.44	1.62	1.91	18%
Number of Charlson comorbidities per admission in the 50 CCS groups	0.26	0.35	0.40	0.47	0.60	28%

A test was also performed to establish how well CBS comorbidity definitions were able to predict mortality in the (H)SMR models, compared to the definitions of Quan *et al.* and Sundararajan *et al.* This was determined using the C statistic (see 2.5.2). The C statistics for the three ICD10 definitions investigated did not differ significantly. The average C statistic for all 50 models was actually exactly equal. The differences in HSMRs between the CBS definition and that of Quan *et al*. were 0.1 on average; between the CBS definition and that of Sundararajan *et al.* they were somewhat larger, namely 1.4 on average, but still well within the confidence intervals. The small size of the differences between CBS and Quan *et al*. is the result of the fact that the CBS definition is mostly based on that of Quan *et al*. Based on these results, it can be concluded that the differences in outcomes between the three ICD10 definitions are small. CBS opted for the CBS definition because - on medical grounds – it believes that this set of ICD10 codes defines the Charlson comorbidities best.

4. Limitations of the HSMR

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

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

- Some hospitals may have on average more seriously ill patients than others, even if they have the same set of scores on the covariates. University hospitals may, for example, have more serious cases than other hospitals. It is questionable whether the model adjusts satisfactorily for this phenomenon. Some essential covariates related to mortality are then missing. This may be caused by some of the desired covariates not (yet) being measured in the LMR/LBZ. 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/LBZ has been far from complete in recent years.

- Hospital admission and discharge policies may differ. For instance, one hospital may admit the same patient more frequently but for shorter stays than another. Or it may discharge a patient earlier than another because there are adequate external terminal care facilities in the neighbourhood. Moreover, hospitals may also allocate health care differently, paying more or less attention to less acute cases. Obviously, all these

situations influence the outcome of the HSMR, as they influence the observed mortality numbers, but these differences in HSMR cannot be translated in terms of quality of care.

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

5. Possibilities for the future

An indicator including early post-discharge mortality alongside in-hospital mortality could be introduced to tackle the problem of range in availability of terminal care outside hospital. Ploemacher *et al*. (2013) saw a decrease in standardised in-hospital mortality in the Netherlands in 2005-2010, which may have been caused by an overall improvement in care quality, but may also be partly explained by substitution of in-hospital mortality by outside-hospital mortality, possibly caused by changes in hospital admission and discharge policies. In cooperation with CBS, Pouw *et al*. (2013) did a retrospective analysis on Dutch hospital data linked to mortality data, and concluded that including early post-discharge mortality is advisable to diminish the effect of discharge bias on the HSMR. In the UK, the SHMI (Summary Hospital-level Mortality Indicator) has been adopted, which includes mortality up to 30 days after discharge (Campbell *et al*., 2011). In 2014, CBS studied the optimal time frame and definition of an indicator including early post-discharge mortality (Van der Laan *et al*., 2014). A fixed period of 45 days after admission in which all mortality is included in the mortality indicator, would make the indicator less dependent on hospital discharge policies. This new indicator has not yet been implemented in the Netherlands. The hospital branch organizations are studying the practical and policy implications of introducing it.

Although including post-discharge mortality in the indicator would reduce the effect of differences between hospital discharge policies, it would not reduce the effect of differences in admission policies for terminally ill patients. Some hospitals admit more patients specifically (and sometimes only) for palliative care than other hospitals. As such patients are admitted to die in hospital, not to receive curative care, these admissions may distort HSMR outcomes. ICD10 allows for coding of palliative care (ICD10 code Z51.5). However, in 2013 this code was not yet used consistently by Dutch hospitals. Furthermore, the present LMR/LBZ registration does not yet allow for distinction between admissions of terminally ill patients for palliative care only and admissions for curative treatment but ending in palliative care. For these reasons, and because of the risk of gaming (see chapter 4), palliative care admissions have not yet been excluded from the calculation of the HSMR. However, the HSMR 2013 reports sent to the hospitals included information on the percentage of the hospital's admissions and deaths related to palliative care as registered in the LMR/LBZ and the overall average. This may to some extent indicate whether or not palliative care could have biased a hospital's HSMR.

To include all relevant mortality in the HSMR, updating or expanding the present "Top 50" diagnosis groups included in the HSMR calculation is also a possibility for future studies.

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Appendix 1. Covariates: definitions and use in regression analyses

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

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

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

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

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

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

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

The SES variable was added to the LMR/LBZ dataset on the basis of the postal code of the patient's residence. SES was derived from the Netherlands Institute for Social Research (SCP)[5], 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. 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

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

"average" if collapsing was necessary. For 2009 and 2010, admissions followed the SES classification of 2006, whereas admissions of 2011 and later 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, the (H)SMR 2009-2011 and the (H)SMR 2010-2012.

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

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

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

there. For the few hospitals that still registered in ICD9-CM in 2013 the diagnoses are converted to ICD10 and then classified according to the ICD10 definitions of the Charlson comorbidities.

All secondary diagnoses registered in the LMR/LBZ 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.

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

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

In conformity with the collapsing procedure for other covariates, comorbidity groups registered in fewer than 50 admissions or that have no deaths are left out, as the two categories of the

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

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

Year of discharge: *2010, 2011, 2012. 2013*.
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/LBZ 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/LBZ

1. Hospitals with fewer than six completely registered months in a year (for inpatient admissions) are excluded. Up to 2010 hospitals were excluded if they had an LMR/LBZ 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, and from 2013 onwards ICD10 code R69).
3. ≤30% of inpatient admissions are coded as acute.
4. ≤0.5 secondary diagnoses are registered per inpatient admission, on average per hospital.[6]

Case mix

Hospitals are excluded if:

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

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

Table A2.1 gives a summary of the hospitals by the different criteria for exclusion for 2013, and Table A2.2 for 2011-2013. (H)SMRs for 2011-2013 are only calculated if hospitals fulfil the criteria in 2013 and in the three-year period as a whole, and responded in all three years. From Table A2.1 it can be concluded that 81 hospitals met (almost) all criteria in 2013 and had granted authorisation. For the period 2011-2013 this is the case for 73 hospitals (see Table A2.2). So HSMR 2013 figures were produced for 81 hospitals, and HSMR 2011-2013 figures for 73 hospitals.

[6] 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, 2013

No.	Criterion	Authorization	No authorization	Total hospitals
0	No inpatient admissions	1	0	1
1	No/partial participation LMR/LBZ	5	3	8
	of which no participation	*5*	*3*	*8*
	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	0	0	0
4	≤ 0.5 secondary diagnoses per inpatient admission (average per hospital)	1	0	1
5	<60 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)	2	0	2
	Meet all criteria	81[a)]	0	81
	Total hospitals	93	3	96

a) For one hospital (H)SMRs were calculated even though it had <6 months of complete registration in 2013. This hospital had a response of >90% of inpatient admissions, not selective with respect to mortality. For five hospitals (H)SMRs were calculated even though the percentage of deaths in the 50 diagnosis groups was slightly lower than 70% in 2013. One of these hospitals also had slightly less acute admissions than the criterion of 30%. All these hospitals are grouped under "Meet all criteria".

Table A2.2. Number of hospitals according to exclusion criteria, 2011-2013

No.	Criterion	Authorization	No authorization	Total hospitals
0	No inpatient admissions	1	0	1
1	No/partial participation LMR/LBZ	7	3	10
	of which no participation in one or more years	*6*	*3*	*9*
	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 / <60 mortality	1	0	1
6	≤ 70% hospital deaths within the 50 diagnosis groups considered	1	0	1
	Does not fulfil >1 of above-mentioned exclusion criteria (1-6)	6	1	7
	Meet all criteria	73[a)]	1	74
	Total hospitals	91	5	96

a) For one hospital (H)SMRs were calculated even though it had <6 months of complete registration in the years 2011-2013. This hospital had a response of >90% of inpatient admissions, not selective with respect to mortality. For one hospital (H)SMRs were calculated even though the percentage of deaths in the 50 diagnosis groups was slightly lower than 70% in 2011-2013. These hospitals are grouped under "Meet all criteria".

Appendix 3. Results of the logistic regressions

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

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

No. CCS group	Severity main diagnosis	Sex	Age	Urgency	Comorbidity_1	Comorbidity_2	Comorbidity_3	Comorbidity_4	Comorbidity_5	Comorbidity_6	Comorbidity_7	Comorbidity_8	Comorbidity_9	Comorbidity_10	Comorbidity_11	Comorbidity_12	Comorbidity_13	Comorbidity_14	Comorbidity_15	Comorbidity_16	Comorbidity_17	SES	Month admission	Year discharge	Source admission
106	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	-	1	-	1	1	1	1
107	1	0	1	1	1	0	1	1	1	1	-	-	1	1	1	-	1	1	-	1	-	0	1	1	1
108	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1
109	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	-	1	-	0	1	1	1
114	1	0	1	1	1	1	1	1	1	1	0	0	1	1	0	0	1	1	-	1	-	0	1	1	1
115	1	1	1	1	1	1	1	1	1	1	0	-	1	0	1	1	1	1	-	1	-	1	0	1	0
116	1	0	1	1	1	1	1	1	1	1	0	-	1	1	1	0	1	1	-	1	-	0	0	1	1
117	1	0	1	1	1	1	1	0	0	0	0	-	1	0	0	0	1	1	-	1	-	0	1	1	1
122	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1	1	1	1	1	1
127	1	1	1	1	1	1	1	1	1	1	0	0	1	1	0	0	1	1	-	1	1	0	1	1	1
129	-	0	1	0	0	1	1	0	0	1	0	-	-	1	-	0	0	1	-	1	-	0	0	0	0
130	1	0	1	1	0	1	0	1	1	1	0	-	1	1	0	-	1	1	-	1	-	0	0	1	1
133	1	1	1	1	1	1	1	1	1	1	1	-	1	1	0	0	1	1	-	1	-	0	1	1	1
145	1	0	1	0	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	0	0	1	0
146	1	0	1	1	1	1	1	0	1	1	1	-	1	0	0	-	1	1	-	1	-	0	0	0	0
149	1	0	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	-	1	1	1	1	1	0
150	1	0	0	1	0	1	0	-	-	1	-	1	1	0	-	-	1	1	-	-	1	0	0	0	1
151	1	0	1	1	0	1	1	1	0	1	1	0	1	0	0	-	1	1	-	1	1	0	0	1	1
153	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	-	1	1	0	0	1	1
155	1	0	1	1	0	1	1	1	1	0	0	1	1	0	0	0	1	1	-	1	-	0	0	1	0
157	1	0	1	1	1	1	0	1	0	1	0	0	1	0	0	-	1	1	-	1	1	1	1	1	1
158	1	1	1	1	1	1	1	1	1	0	0	-	0	0	0	-	0	1	-	1	-	0	0	1	1
159	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	-	1	1	0	0	1	1
226	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	0	1	1	-	1	-	0	0	1	0
233	1	1	1	0	1	1	1	1	0	1	0	-	1	0	0	0	1	1	-	1	-	1	0	0	0
237	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	-	1	1	0	0	1	1
238	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	-	1	0	1	1	1	1
249	-	0	1	0	1	1	1	0	-	1	-	1	1	0	-	-	1	1	-	1	-	0	0	1	0
Total	44	19	48	42	38	49	34	43	27	43	9	18	42	24	11	11	46	41	0	45	14	12	16	40	32

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

No. CCS group	Severity main diagnosis	Sex	Age	Urgency	Comorbidity_1	Comorbidity_2	Comorbidity_3	Comorbidity_4	Comorbidity_5	Comorbidity_6	Comorbidity_7	Comorbidity_8	Comorbidity_9	Comorbidity_10	Comorbidity_11	Comorbidity_12	Comorbidity_13	Comorbidity_14	Comorbidity_15	Comorbidity_16	Comorbidity_17	SES	Month admission	Year discharge	Source admission
2	980	42	956	0	22	134	44	12	17	27	1	13	52	14	0	3	61	106	-	95	31	8	30	15	27
12	0	0	9	290	4	25	1	8	-	3	2	-	7	4	-	-	7	0	-	95	-	3	7	7	13
13	0	1	53	306	20	8	3	12	-	10	1	0	-	0	0	-	22	2	-	87	-	6	4	19	1
14	26	17	394	636	44	111	11	23	0	15	3	21	59	3	0	-	68	7	-	263	-	13	8	68	23
15	3	7	127	273	10	23	9	10	0	5	0	-	2	2	1	-	33	0	-	66	-	1	3	11	15
17	8	0	60	238	12	36	5	10	-	4	0	-	6	9	2	-	27	0	-	94	-	8	6	43	0
19	79	29	118	3390	22	132	10	53	2	54	1	9	53	2	2	1	70	9	-	260	-	6	5	86	87
24	18	0	24	753	2	12	0	4	0	2	0	-	41	0	-	-	21	0	-	180	-	3	2	5	3
29	4	-	65	201	3	14	0	6	0	4	0	-	-	1	-	-	26	0	-	184	-	6	6	3	2
32	24	0	31	496	7	27	1	19	0	2	1	-	-	12	1	-	43	11	-	281	-	3	6	19	3
38	22	0	98	418	14	45	0	9	-	8	6	9	62	0	2	3	86	24	1	27	-	5	13	5	77
39	86	4	265	235	13	42	0	27	-	6	2	-	5	5	-	-	31	9	-	1	-	5	2	8	30
42	83	1	147	1660	17	154	24	45	1	31	2	11	26	5	0	0	99	1	-	362	32	16	10	111	35
44	27	3	57	100	3	27	0	10	3	10	1	-	4	2	-	0	7	7	-	3	-	1	3	6	2
50	85	0	168	42	26	98	49	4	7	6	0	-	24	0	3	1	62	8	-	3	-	4	13	54	4
55	432	19	301	0	3	74	2	2	8	15	1	-	0	0	0	5	3	9	-	32	11	5	7	17	5
59	165	1	70	75	0	109	3	7	2	5	0	4	1	0	2	1	14	3	-	55	13	1	4	16	21
85	402	2	86	8	2	13	0	9	2	29	-	-	10	0	-	-	2	9	-	20	-	3	4	9	2
96	147	0	214	114	24	162	22	24	7	12	4	-	27	0	4	3	88	2	-	3	-	12	4	22	44
100	774	0	1443	24	4	592	33	106	22	52	0	2	68	16	19	5	80	73	-	22	-	32	7	84	41
101	115	3	540	76	8	377	17	49	3	23	0	8	26	12	4	0	103	25	-	17	-	2	7	35	92
103	107	3	271	22	21	168	2	84	17	23	2	-	17	4	1	-	24	27	-	58	-	4	11	26	48
106	672	19	662	80	0	259	6	41	24	61	0	17	11	13	14	3	60	32	-	42	-	22	18	63	44
107	645	1	275	165	13	1	16	8	5	66	-	-	10	15	4	-	17	13	-	4	-	8	17	66	80
108	-	21	1259	117	43	23	51	117	65	125	17	31	47	5	7	13	386	52	-	82	39	13	80	172	80

No. CCS group	Severity main diagnosis	Sex	Age	Urgency	Comorbidity_1	Comorbidity_2	Comorbidity_3	Comorbidity_4	Comorbidity_5	Comorbidity_6	Comorbidity_7	Comorbidity_8	Comorbidity_9	Comorbidity_10	Comorbidity_11	Comorbidity_12	Comorbidity_13	Comorbidity_14	Comorbidity_15	Comorbidity_16	Comorbidity_17	SES	Month admission	Year discharge	Source admission
109	7626	5	2201	58	103	617	15	47	47	80	0	4	44	11	2	41	76	146	-	80	-	9	29	162	25
114	1107	2	331	419	30	200	51	22	7	23	1	2	18	7	2	1	68	25	-	16	-	1	14	41	25
115	1504	26	581	380	7	33	10	19	9	24	0	-	22	1	10	4	44	8	-	17	-	10	6	15	2
116	155	0	163	325	16	107	14	28	9	20	3	-	13	5	7	2	53	12	-	9	-	4	7	29	6
117	258	1	131	56	4	51	42	1	2	1	0	-	35	0	2	0	24	10	-	11	-	7	13	8	22
122	99	32	2980	0	145	755	28	134	64	6	13	14	66	3	2	34	153	417	0	282	53	17	22	128	92
127	90	7	503	107	17	405	36	20	12	18	2	2	13	6	0	1	70	23	-	27	8	5	70	25	59
129	-	2	171	1	4	30	9	0	3	5	1	-	-	5	-	0	0	9	-	18	-	6	1	1	3
130	31	0	231	77	3	15	0	7	4	32	1	-	32	12	0	-	19	10	-	74	-	4	11	22	36
133	1115	22	648	506	5	207	11	14	26	88	11	-	83	7	4	3	31	165	-	133	-	5	19	35	135
145	241	2	1038	2	6	105	19	14	12	70	7	-	24	14	5	14	92	34	-	54	-	4	3	47	2
146	104	1	301	37	18	77	13	2	13	17	11	-	48	2	0	-	43	36	-	31	-	2	8	2	5
149	202	0	484	15	11	122	3	21	9	27	1	12	27	8	11	4	65	21	-	33	14	10	12	35	2
150	30	0	11	83	1	26	1	-	-	5	-	6	5	1	-	-	31	7	-	-	110	1	3	4	13
151	459	0	131	86	2	39	11	8	1	6	11	1	11	1	1	-	68	10	-	51	69	3	10	33	82
153	282	5	225	9	6	198	16	39	8	15	1	1	80	1	1	2	64	29	-	104	7	5	7	14	17
155	1373	1	234	26	0	22	18	6	5	4	1	10	5	2	1	1	37	8	-	59	-	5	1	12	6
157	6	0	378	41	19	127	3	4	3	9	0	0	6	0	1	-	6	7	-	47	35	13	20	33	21
158	6	9	228	208	9	56	8	6	6	1	0	-	2	1	1	-	2	4	-	13	-	5	2	17	35
159	70	5	585	14	15	192	8	20	5	13	1	11	17	19	4	7	64	6	-	61	12	6	11	47	22
226	9	192	709	1	100	731	9	57	22	79	1	11	129	6	13	2	138	20	-	32	-	2	9	78	0
233	2263	25	474	0	21	77	4	25	4	9	1	-	14	3	1	1	9	4	-	14	-	14	7	3	6
237	317	7	355	159	30	214	57	36	17	33	5	16	78	8	1	9	38	19	-	15	9	2	5	20	75
238	461	0	496	16	9	151	21	20	15	40	2	8	23	21	7	5	65	31	-	61	0	14	15	49	174
249	-	1	191	1	19	12	5	1	-	7	-	10	22	2	-	-	6	9	-	23	-	5	7	14	1
Total	22713	520	21475	12346	936	7235	725	1251	489	1225	118	233	1376	272	143	169	2702	1500	1	3601	443	347	589	1842	1643

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

No. CCS group	Severity main diagnosis	Sex	Age	Urgency	Comorbidity_1	Comorbidity_2	Comorbidity_3	Comorbidity_4	Comorbidity_5	Comorbidity_6	Comorbidity_7	Comorbidity_8	Comorbidity_9	Comorbidity_10	Comorbidity_11	Comorbidity_12	Comorbidity_13	Comorbidity_14	Comorbidity_15	Comorbidity_16	Comorbidity_17	SES	Month admission	Year discharge	Source admission
2	4	1	20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	4	5	3	2
12	1	1	11	1	1	1	1	1	-	1	1	-	1	1	-	-	1	1	-	1	-	4	5	3	2
13	1	1	13	1	1	1	1	1	-	1	1	1	-	1	1	-	1	1	-	1	-	4	5	3	2
14	3	1	14	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	-	1	-	5	5	3	2
15	2	1	12	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	4	5	3	2
17	2	1	11	1	1	1	1	1	-	1	1	-	1	1	1	-	1	1	-	1	-	4	5	3	2
19	3	1	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	5	5	3	2
24	2	1	13	1	1	1	1	1	1	1	1	-	1	1	-	-	1	1	-	1	-	4	5	3	1
29	1	-	9	1	1	1	1	1	1	1	1	-	-	1	-	-	1	1	-	1	-	4	5	3	1
32	2	1	12	1	1	1	1	1	1	1	1	-	-	1	1	-	1	1	-	1	-	5	5	3	2
38	5	1	15	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	-	4	5	3	2
39	6	1	19	1	1	1	1	1	-	1	1	-	1	1	-	-	1	1	-	1	-	5	5	3	2
42	4	1	18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
44	4	1	15	1	1	1	1	1	1	1	1	-	1	1	-	1	1	1	-	1	-	4	5	3	2
50	4	1	14	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	5	5	3	2
55	3	1	16	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	1	4	5	3	2
59	2	1	18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	4	5	3	2
85	1	1	19	1	1	1	1	1	1	1	-	-	1	1	-	-	1	1	-	1	-	4	5	3	2
96	5	1	15	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	5	5	3	2
100	2	1	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	5	5	3	2
101	3	1	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	4	5	3	2
103	3	1	17	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	5	5	3	2
106	2	1	19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	5	5	3	2
107	2	1	15	1	1	1	1	1	1	1	-	-	1	1	1	-	1	1	-	1	-	4	5	3	2
108	-	1	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2

No. CCS group	Severity main diagnosis	Sex	Age	Urgency	Comorbidity_1	Comorbidity_2	Comorbidity_3	Comorbidity_4	Comorbidity_5	Comorbidity_6	Comorbidity_7	Comorbidity_8	Comorbidity_9	Comorbidity_10	Comorbidity_11	Comorbidity_12	Comorbidity_13	Comorbidity_14	Comorbidity_15	Comorbidity_16	Comorbidity_17	SES	Month admission	Year discharge	Source admission
109	4	1	19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	5	5	3	2
114	4	1	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	5	5	3	2
115	5	1	12	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	4	5	3	2
116	3	1	13	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	4	5	3	2
117	4	1	18	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	5	5	3	2
122	5	1	20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	5	3	2
127	2	1	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
129	-	1	18	1	1	1	1	1	1	1	1	-	-	1	-	1	1	1	-	1	-	4	5	3	2
130	3	1	17	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	4	5	3	2
133	5	1	20	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	5	5	3	2
145	3	1	18	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	5	5	3	2
146	2	1	11	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	4	5	3	2
149	4	1	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	4	5	3	2
150	1	1	10	1	1	1	1	-	-	1	-	1	1	1	-	-	1	1	-	-	1	4	5	3	2
151	6	1	16	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	-	1	1	4	5	3	2
153	5	1	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
155	5	1	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	4	5	3	2
157	1	1	17	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	-	1	1	4	5	3	2
158	1	1	13	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1	-	1	-	4	5	3	2
159	3	1	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	5	5	3	2
226	1	1	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	5	5	3	2
233	8	1	20	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	-	5	5	3	2
237	3	1	19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	4	5	3	2
238	6	1	19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	4	5	3	2
249	-	1	13	1	1	1	1	1	-	1	-	1	1	1	-	-	1	1	-	1	-	4	5	3	2
Total	151	49	758	50	50	50	50	49	43	50	46	26	46	50	41	31	50	50	2	49	15	222	250	150	98

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

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

Appendix 4 Summaries of individual models

In “Coefficients HSMR 2013.xls” the coefficients and standard errors for the logistic regressions of inpatient mortality are presented for each CCS diagnosis group, as explained in section 3.3.

Explanation of symbols

.	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
2013–2014	2013 to 2014 inclusive
2013/2014	Average for 2013 to 2014 inclusive
2013/'14	Crop year, financial year, school year, etc., beginning in 2013 and ending in 2014
2011/'12–2013/'14	Crop year, financial year, etc., 2011/'12 to 2013/'14 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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