Methodological paper

Hospital Readmission Ratio

Methodological report of the 2016 models

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1. Introduction

1.1 Indicators of quality of hospital care

Overall quality of hospital care can be estimated using several types of quality indicators based on hospital admission data. Such indicators for identifying potentially suboptimal quality of hospital care might focus for example on unexpected in-hospital or post-discharge mortality, potentially preventable hospital readmissions or unexpected long duration of admissions. In the Netherlands, hospital admission and discharge data is registered in the LBZ, a national hospital discharge register covering all general, university and three specialised hospitals. Other specialised clinics, independent treatment centres and private clinics are not included. Inpatients as well as day cases and prolonged observations without overnight stay are registered. For each hospital discharge administrative data of the admission are registered, as well as diagnoses and procedures.

In the Netherlands, hospitals participating in the LBZ registration are annually provided by Dutch Hospital Data (DHD) with a set of indicators based on their performance in the previous year. Up to 2016 this set included the (unadjusted) hospital readmission rate, which is the ratio of the number of observed readmissions to the total number of hospital admissions. However, since this ratio does not correct for case-mix differences, it might be less indicative of differences in the true number of potentially preventable readmissions. Therefore, in 2017 DHD has asked Statistics Netherlands to develop a model to estimate the expected readmission risks adjusted for relevant covariates, in a fashion similar to the estimation of the hospital standardized mortality rates (HSMR).

1.2 Predictive value of the hospital readmission model

Internationally, models for estimating hospital readmission rates are used for the purpose of risk stratification but also as a quality indicator. From previous studies it is known that several patient characteristics can contribute to the risk to be readmitted to the hospital. In a systematic review by Kansagara *et al.* (2011), an overview is presented of the various validated models that have been used internationally, the covariates included in those models and their overall predictive value. Common covariates include comorbidity indexes, age, sex and/or prior use of medical services (hospitalizations). Regardless of the number of included covariates, the results of only a small fraction of the models are moderately discriminative (AUC/C-statistic>0.70). The model developed by Statistics Netherlands includes additional covariates such as severity of the main diagnosis, urgency of the admission and socio-economic status. However, the overall predictive value of the model did not exceed previously published values (AUC=0.69). It was demonstrated though, that the level of case mix correction applied by the model significantly improved comparability of the outcomes of the individual hospitals. So, although the case mix correction is probably incomplete, it does, to some extent, reduce effects due to differences in patient populations. As such, applying the model to calculate adjusted readmission ratios for individual hospitals is an improvement over calculating crude rates.

1.3 Aim of the current project

The model developed last year by Statistics Netherlands (referred to as the '2015 model'; Van der Laan *et al.* 2017a) was based on the linkage of admissions and readmissions that occurred within the same hospital (intra-hospital readmissions). However, readmissions can also take place in other hospitals. Therefore it might be more accurate to also identify and include so-

called inter-hospital readmissions in the model. A more complete estimation of the actual number of admissions and readmissions might improve the predictive value of the model. However, it is also common practice for hospitals to refer inpatients to neighbouring or specialized hospitals for specific procedures, such as coronary interventions. Such planned transfers should not be identified as readmissions. In addition, when using a model that is based on identifying readmissions within the same hospital only ('intra-hospital model'), some of the supposed readmissions are in fact transfers from other hospitals and should not be linked to a previous index admission in the first hospital.

In order to evaluate whether including inter-hospital readmissions and excluding transfers improves model outcome, the current project compared the results of both an intra- and an inter-hospital approach to linkage of index admissions and readmissions. These investigations are described in chapter 5. On the basis of these investigations it was decided to publish two final models for the '2016 model': an intra-hospital model and an inter-hospital model. These models are described in chapters 3 and 4.

1.4 Output

Statistics Netherlands has only calculated the models for the hospital readmission risks, not the outcomes for the individual hospitals. Statistics Netherlands has calculated the present models on the basis of LBZ data of 2015-2016. For their regular hospital indicators reports, DHD will use the intra-hospital model to estimate the expected readmission risk, adjusted for relevant covariates, for each individual primary (index) hospital admission in 2017. For each hospital the standardized (adjusted) readmission ratio can be calculated as the observed number of readmissions (x 100) divided by the sum of the expected readmission risks of the index admissions of that hospital. On request of individual hospitals, DHD can also calculate the readmission ratio based on the inter-hospital model.

2. Methods

2.1 Changes compared to the previous (2015) model

In the current project two separate 2016 models were produced and evaluated: the first model is largely similar to the final 2015 model and is based on identifying intra-hospital readmissions, while the second model additionally identifies and includes inter-hospital readmissions, aiming to improve model outcome by using more complete data with regard to the total number of readmissions.

When using an inter-hospital approach it is important to not label planned transfers as readmissions of a previous inpatient stay in another hospital. Therefore, transfers between hospitals were identified and excluded as readmissions. In addition, it was defined that index admissions followed by a transfer could not have a readmission. Contrary to the 2015 model, these transfer rules were now also applied to the intra-hospital model, in order to not incorrectly label transfers from other hospitals as readmissions (i.e. the 'to and fro' transfers from hospital A to hospital B and back to hospital A: the latter admission in hospital A is now not considered to be a readmission of the first admission in hospital A).

To allow identification of inter-hospital (re)admissions or transfers of a single person, the hospital-specific patient identification numbers, which were used as identifiers in the 2015 model, cannot be used. However, Statistics Netherlands has linked the LBZ data to the national population register, on the basis of which a unique (pseudonymised) personal identifier could be added to the LBZ dataset. Using this personal identifier, nearly all admissions of a single person in the hospitals participating in the LBZ, can be identified. In addition, it is known that errors can occur in the registration of the hospital-specific patient ID number, e.g. when hospitals merge. Bias due to these administrative errors in the intra-hospital model is eliminated when using the personal identifier for linking admissions. Therefore this identifier was used for both the inter- and intra-hospital models of 2016.

Finally, in the current 2016 models we included LBZ data from both 2015 and 2016 and 'year' was added to the model covariates. The methods used in the 2016 models are described in more detail in the next paragraphs.

2.2 Readmission ratio

The (hospital) readmission ratio is calculated using the expected (hospital) readmission risk as the denominator and observed readmission as the numerator. The expected readmission risk is predicted for each individual admission within a given period, adjusted for patient and admission characteristics of that admission as covariates. Readmission risk was predicted for all (index) admissions that potentially could be followed by a readmission, excluding admissions for diagnoses with complex care paths where planned readmissions are often involved. *Readmissions are defined as those admissions that occurred within 30 days of the discharge date of the preceding index admission*. Detailed information on the characteristics and criteria of index admissions and readmissions is given in paragraphs 2.3.5 and 2.3.6 respectively.

Expected readmission risk is determined for each of the included diagnosis groups, which are based on the CCS *(Clinical Classifications Software*[1]), which clusters ICD codes of the main diagnoses of the admissions into 259 clinically meaningful categories. In accordance with the HSMR, we further clustered these groups into 157 diagnosis groups, which are partly the same clusters used for the SHMI (Summary Hospital-level Mortality Indicator) in the UK (HSCIC, 2016). To determine readmission risk we used logistic regression models, with an observed readmission as the target (dependent) variable and various variables available in the LBZ as covariates.

The methodology for estimating the expected readmission risk is very similar to that used for estimating expected mortality rates applied for calculating the HSMR rates, described in detail elsewhere (Van der Laan *et al.* 2017b). In the following section we therefore briefly describe the applied methods, while deviations from the HSMR methodology or other methods specific to the current project are described in more detail.

2.3 Target population and data set

2.3.1 Patient identifier

Statistics Netherlands has linked the LBZ data to the Dutch national population register, using a pseudonym of the national personal identification number, and the combination of date of birth, sex and postal code as linkage keys. Through this linkage a unique pseudonymised person ID could be added to the LBZ dataset. With this linkage >99% of all admissions could be uniquely linked to a person in the population register; thus the loss of data was minimal (<1%). Using this identifier not only allows identification of transfers and inter-hospital readmissions, it also eliminates bias due to administrative errors in hospital-specific patient numbers.

2.3.2 Admissions – general criteria

We consider both the population of hospitals and the population of admissions. Our population of (re)admissions consists of "all hospital stays (inpatient admissions) of Dutch residents in Dutch short-stay hospitals within the study period". Only completely registered admissions with a registered main diagnosis were included. In the LBZ, the date of discharge, and not the day of admission, determines the LBZ year a record is assigned to. Therefore, the registered hospital stays of year *t* comprise all inpatient admissions that ended in year *t*. Day cases and prolonged observations were excluded, since subsequent readmissions might be elective, for example, for prolonged treatment.

In addition, admissions of foreigners were excluded from the model, since readmissions might have also taken place in a hospital in their residential country. Furthermore, foreigners cannot be linked to the Dutch population register. The number of admissions of foreigners is relatively small.

Lastly, duplicate admissions were removed. This included admissions with identical values for date and time of admission and of discharge in combination with identical values for either (1) hospital ID and hospital-specific patient ID or (2) the pseudonymised person ID. In case of duplicate admissions, the admission with the lowest LBZ registration number was removed and

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

the one with the highest LBZ registration number was kept, since we assumed that the latter admission might have been registered as a corrected version of the first.

2.3.3 Hospitals

Hospitals report admission data (hospital stay data) in the LBZ. However, not all hospitals participate in the LBZ. In principle, the hospital readmission risk model includes all general hospitals, all university hospitals and short-stay specialised hospitals with inpatient admissions participating in the LBZ in the study period. One of the short-stay specialised hospitals was excluded since it mostly treats patients with oncological disease, which are excluded from the data (see paragraph 2.3.5).

The readmission ratio is calculated using LBZ data on admissions, using the pseudonymised personal ID as the unique key for identifying (re)admissions. For the intra-hospital model, the combination of the person ID (for identifying patients) and the hospital ID number (for identifying the same hospital) was used for linking admissions. In case of merging hospitals, the hospital ID number the hospital used in the LBZ registration year (based on the discharge dates of the admissions), was used for the associated study period in the models. For example, two hospitals that had merged in 2016 were, for the intra-hospital approach, analysed as separate units for study period 2015 and as a single unit for study period 2016. If the hospitals would have been analysed as a single merged hospital for both years, transfers between both hospitals could not be identified and excluded in 2015 and would be labelled as readmissions, thus negatively influencing their readmission rates.

2.3.4 Study periods

For the calculation of the current models, LBZ data of 2015 and 2016 was available. In 2015, a small number of hospitals had not completely registered all data in the LBZ. However, for the identification of inter-hospital readmissions and transfers, it is essential that all hospitals have registered all admissions. If, for instance, LBZ data from a certain month is not complete, transfers and inter-hospital readmissions in the hospital with incomplete data are missed, thus influencing outcome of other hospitals. Therefore, for 2015 we decided to only use LBZ data for the period in which all hospitals had completely registered their data, namely all admissions with a discharge date from April 1st 2015.

Previously we showed that using index admissions with a discharge date from November 1st of year t-1 up to October 31st of year t (study period) is optimal to identify the highest percentage of readmissions ending in year t (Van der Laan *et al.* 2017a). Thus, for study period 2015 ('year'=2015 in the model) we selected index admissions with a discharge date from April 1st 2015 up to October 31st 2015, while for 2016 (where all hospitals had completely registered all inpatient data) we selected index admissions with a discharge date from November 1st 2015 up to October 31st 2016 ('year'= 2016 in the model).

Using these study periods, admissions with a discharge date between November 1st 2015 and December 31st 2015 can potentially be linked to index admissions from either 2015 or 2016. Since for the intra-hospital approach we decided to use the hospital ID number the hospitals had used in the year of the actual registration of data, it was not possible to merge the LBZ data from both years into a single set for identification of readmissions and transfers, since hospital ID numbers could have changed between 2015 and 2016 due to merging. As a result, admissions from the above-mentioned two-month period should potentially be analysed using old and new hospital IDs and should be added twice to the dataset with different hospital IDs.

To avoid this issue, data from both LBZ years were processed separately for the identification of the index admissions, transfers and readmissions in each study period. After this processing, all index admissions of both study periods were combined into a single dataset that was entered into the models.

2.3.5 Criteria for index admissions

Expected readmission risk was only calculated for those inpatient admissions (meeting the general criteria for admissions, see 2.3.2) for which readmission was possible (i.e. patient did not die during the index admission), and excluding some specific diagnosis groups. These admissions are referred to as index admissions. Thus, in summary, the index admissions had to meet the following criteria:

- The patient did not die during the admission.
- The main diagnosis of the admission was not related to oncology (CCS groups 11-45) or psychiatry (CCS groups 65-75) since hospital care for these diagnoses is usually complex and follow-up care might be required. In addition the main diagnosis was not related to obstetrics (CCS groups 176-196; 218), since most deliveries do not take place during inpatient admissions, so it cannot be determined whether an admission for this purpose is the 'true' index admission.
- The date of discharge was from April 1st 2015 up to October 31st 2015 ('year'= 2015) or from November 1st 2015 up to October 31st 2016 ('year'= 2016).

2.3.6 Criteria for potential readmissions

Inpatient admissions only qualified as potential readmissions (meeting the general criteria for admissions, see 2.3.2) if the following criteria were matched:

- The main diagnosis of the admission was not related to oncology (CCS groups 11-45) or psychiatry (CCS groups 65-75) since hospital care for these diagnoses is usually complex and follow-up care might be required. In addition the main diagnosis was not related to obstetrics (CCS groups 176-196; 218), since most deliveries do not take place during inpatient admissions, so it cannot be determined whether an admission for this purpose is a "true" readmission.
- The main diagnosis of the admission was not related to social, socio-economic or psychosocial circumstances or administrative purposes (ICD10: Z55-Z65), other circumstances (ICD10: Z70-Z76) or screening, follow-up care or rehabilitation (CCS groups 254-258), since admissions for these purposes are usually planned.
- The discharge date of the admission was before or on December 31st of year *t*.
- The maximal time lapse between the admission date of the readmission and the discharge date of the index admission is 30 days (29 days interval at maximum). For example, when an index admission has a discharge date of January 1st, a subsequent admission on January 30th is classified as a readmission, while a subsequent admission on January 31st is not.
- If a readmission in the same hospital started on the same day as the discharge date of the index admission), the minimal time lapse between both admissions is one hour. If the hour of discharge of the index admission or the hour of admission of the readmission is unknown in this specific situation, the subsequent admission is not identified as a readmission.
- Using the inter-hospital approach, an admission is considered a readmission in another hospital if the date of admission in hospital B is at least one day later than the date of discharge in hospital A. If a patient is admitted in hospital B on the date of discharge in hospital A, the second admission is not considered a readmission but a (planned) transfer, see 2.3.7.

Note that the main diagnosis of the readmission does not have to be related to the main diagnosis of the index admission.

2.3.7 Transfers

In the 2016 models transfers were not labelled as readmissions. Transfers are defined as admissions with a date of admission that was identical to the date of discharge of the previous admission in another hospital. In case of 'overlapping admissions' in two different hospitals (i.e. the start date of the second admission preceded the date of discharge in the first hospital) the second admission was also labelled as a transfer. Transfers affect the identification of readmissions in two ways:

First, when index admissions are followed by a transfer, these index admissions (by definition) cannot have a readmission. Thus, when an index admission of a person is followed by a transfer to another hospital and subsequently by a 'true' readmission, the readmission is assigned to the transfer admission instead of to the initial index admission. In case of several consecutive transfers, a readmission can only be assigned to the last transfer of the sequence. Although index admissions that are followed by a transfer cannot have readmissions, it was decided to keep these index admissions in the model. The effect of excluding these index admissions from the model is described in chapter 5.

Second, transfers cannot be readmissions. This is not only relevant for the inter-hospital model, but also for the intra-hospital model that only considers readmissions in the same hospital. In case of 'to and fro' transfers from hospital A to hospital B and back to hospital A, in the 2016 models the latter admission in hospital A is *not* a readmission of the first admission in hospital A; while in the 2015 model it was. In fact, in the present models an admission in hospital A that is a transfer from hospital B can (by definition) never be a readmission of any other previous admission.

The general criteria for admissions and the additional criteria for index admissions, intra-hospital and inter-hospital readmissions and the role of transfers are summarised in table 2.3.7.1.

2.3.7.1 General criteria, additional criteria for index admissions and readmissions and the influence of transfers.

	Criteria for index admissions	Criteria for potential readmissions
General	- Inpatient admissions registered in the LBZ - Completely registered admissions with a registered main diagnosis - Admissions of Dutch residents	- Inpatient admissions registered in the LBZ - Completely registered admissions with a registered main diagnosis - Admissions of Dutch residents
Follow-up	The patient did not die during the admission.	
Diagnosis	The main diagnosis of the admission was not related to oncology (CCS groups 11-45), psychiatry (CCS groups 65-75) or obstetrics (CCS groups 176-196; 218).	The main diagnosis of the admission was not related to oncology (CCS groups 11-45), psychiatry (CCS groups 65-75), obstetrics (CCS groups 176-196; 218), social, socio-economic or psychosocial circumstances or administrative purposes (ICD10: Z55-Z65), other circumstances (ICD10: Z70-Z76) or screening, follow-up care or rehabilitation (CCS groups 254-258).
Period	For year t in the model the date of discharge was from November 1st year t-1 up to October 31st year t ('year'= t). [For year 2015 this was adapted: from April 1st 2015 up to October 31st 2015]	The discharge date of the admission was before or on December 31st of year *t*.
Maximal time lapse		- The maximal time lapse between the admission date of the readmission and the discharge date of the index admission is 30 days (29 days interval at maximum)
Minimal time lapse		- Intra-hospital readmission: if the readmission started on the same day as the discharge date of the index admission, the minimal time lapse between both admissions is one hour - Inter-hospital readmission: the date of admission in hospital B (readmission) is at least one day later than the date of discharge in hospital A (index admission)
Influence of transfers[1]	Index admissions followed by a transfer cannot have a readmission.	Transfers cannot be readmissions.

[1] A transfer is an admission in hospital B with a date of admission that is identical to the date of discharge of a previous admission in hospital A.

2.4 Target variable

The target variable for the regression analysis of both models is the occurrence of a readmission within 30 days of the discharge date of the preceding index admission.

The pseudonymised person ID (resulting after linkage of the LBZ to the national population register) was used as the unique key for identifying admissions of the same patient in a single hospital (intra-hospital model) or across all hospitals (inter-hospital model).

The dataset is composed based on the criteria presented in section 2.3. According to the criteria for index admissions and readmissions, two variables are added to the dataset to mark both types of admissions. Readmissions can also count as index admissions in case they are followed by another readmission.

After that, the dataset is processed twice to allocate readmissions to index admissions: once for the intra-hospital model and another time for the inter-hospital model. For the intra-hospital model, index admissions and potential readmissions of the same patient (person ID) are identified within the same hospital only. For the inter-hospital model index admissions and potential readmissions of the same person ID are identified across all hospitals, including potential readmissions in the same and in other hospitals.

Within each set of admissions per patient, for each index admission the presence of a readmission within 30 days is determined. Each index admission can only be followed by a single subsequent readmission, and a single readmission can also be only allocated to a single index admission. If an index admission is followed by multiple potential readmissions within 30 days, only the first occurring readmission is marked as such. Based on this algorithm, for each index admission the presence of a readmission is marked.

Transfers are identified according to the method presented in section 2.3.7. After that, the previously described rules are applied (‘an admission followed by a transfer cannot have a readmission’ and ‘a transfer cannot be a readmission’) to both datasets, with the result that some of the admissions are no longer regarded as readmissions. The index admissions associated with those readmissions were initially marked as having a readmission, but since these readmissions are no longer categorized as such after applying the transfer rules, the presence of a readmission is cleared from the respective index admissions.

Subsequently, for both datasets all index admissions and the corresponding covariates are selected, plus the target variable (whether the primary admission was followed by a readmission or not) and these were entered into the models.

To illustrate the implementation of excluding transfers from the models, an example is given in table 2.4.1.

2.4.1 Example of the identification of readmissions after excluding transfers.

		Step 1		Step 2		Step 3	
Admission	**Hospital**	**Intra-hospital model: is the admission followed by a readmission?**	**Inter-hospital model: is the admission followed by a readmission?**	**Is the admission followed by a transfer?**	**Is the admission a transfer?**	**Intra-hospital model: is the admission followed by a readmission (after correction for transfers)?**	**Inter-hospital model: is the admission followed by a readmission (after correction for transfers)?**
A1	A	Yes (A2)	Yes (B1)	No	No	No, A2 is a transfer	Yes (B1)
<patient is home>							
B1	B	Yes (B2)	Yes (B2)	Yes (A2)	No	No, B2 is a transfer	No, B2 is a transfer
A2	A	Yes (A3)	Yes (A3)	Yes (B2)	Yes (of B1)	No, A2 is followed by a transfer (B2)	No, A2 is followed by a transfer (B2)
B2	B	No	Yes (A3)	No	Yes (of A2)	No	Yes (A3)
<patient is home>							
A3	A	No	No	No	No	No	No

In this example a patient is admitted five times to two different hospitals within a period of 30 days. All admissions are index admissions, and admissions B1, A2 and B2 are consecutive admissions (date of admission of A2 is equal to date of discharge of B1; and date of admission of B2 is equal to date of discharge of A2). According to the criteria for readmissions, in step 1 the presence of readmissions is determined for both the intra- and the inter-hospital model. After that, the presence of transfers is determined in step 2. Finally, the information of steps 1 and 2 is combined into step 3: the presence of readmissions corrected for transfers, where we apply the rules ‘an index admission followed by a transfer cannot have a readmission’ and ‘a transfer cannot be a readmission’.

For example, in the intra-hospital model A2 is a possible readmission to A1, but since A2 is a transfer, it cannot be a readmission. As a result, A1 is not followed by a readmission. In addition, A3 is not a readmission of A2 (intra-hospital model), since A2 is followed by a transfer (B2) and thus cannot have a readmission. Only the admissions A1 and B2 are still followed by a readmission (in the inter-hospital model only) after excluding transfers, since these admissions are not followed by transfers and the identified readmissions (B1 and A3 respectively) are not identified as transfers.

2.5 Stratification

Instead of performing one logistic regression for all admissions, we performed a separate logistic regression for each main diagnosis group. These sub-populations of index admissions are more homogeneous than the entire population. Hence, this stratification may improve the precision of the estimated readmission probabilities. As a result of the stratification, covariates are allowed to have different regression coefficients across diagnosis groups. Due to the exclusions of specific CCS groups for the index admissions, 35 of the 157 diagnosis groups (as used for the HSMR) are fully excluded. Therefore, the model included 122 separate logistic regressions, one for each diagnosis group selected (see Appendix III for the diagnosis groups included).

2.6 Covariates (explanatory variables or predictors of readmission risk)

By including covariates of patient and admission characteristics of the index admissions in the model, the hospital readmission risk is adjusted for these characteristics. For this purpose we selected the same covariates that are also regularly used in the (H)SMR model estimations, which are variables (available in the LBZ) known to be associated with in-hospital mortality. During the development of the readmission model, it was demonstrated that these covariates indeed contributed to the predictive value of the model (Van der Laan *et al.* 2017a).

The LBZ variables that are included in the model as covariates are age, sex, socio-economic status, severity of main diagnosis (based on mortality risk categories), urgency of admission, Charlson comorbidities, source of admission, month of admission and year. These variables are described below. Detailed information on these variables and their content is available in the HSMR methodology report (Van der Laan *et al.* 2017b). For the variables socio-economic status, severity of main diagnosis and source of admission the detailed classifications are presented in the file 'Classification of variables', published together with the methodology report of the HSMR (Van der Laan *et al.* 2017b). The variable year is different from the variable used for the HSMR model, since it reflects the study period the index admission belongs to, rather than year of discharge. The specific (modified) definitions of 'year' for the 2016 models are described in 2.3.4.

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 used the first category of each covariate as the reference category.

Covariates:

- **Age at admission** (in years): *0, 1-4, 5-9, 10-14, …, 90-94, 95+*.
- **Sex** of the patient: *male, female.*
- **SES (socio-economic status)** of the postal area of patient's address: *lowest, below average, average, above average, highest, unknown.*
- **Severity of main diagnosis** groups: *[0-0.01), [0.01-0.02), [0.02-0.05), [0.05-0.1), [0.1-0.2), [0.2-0.3), [0.3-0.4), [0.4-1], Other*.
- **Urgency** of the admission: *elective, acute.*

- **Comorbidity_1 – Comorbidity_17**. All these 17 covariates are dummy variables, having categories: *0* (*no*) and *1* (*yes*).
- **Source of admission**: *home, nursing home or other institution, hospital.*
- **Month of admission.** Six 2-month periods: *January/February, …, November/December.*
- **Year.** Year of the study period (generally for index admissions year t is defined by a discharge date from November 1st of year t-1 up to October 31st): *2015, 2016*.

2.7 Estimation of the models

Logistic regression models were estimated for each of the 122 diagnosis groups using the variables of the index admissions mentioned in the previous paragraph and the dichotomous variable indicating whether an admission was followed by a readmission as the target variable. This was done for both the datasets that had been processed for intra- and inter-hospital readmissions respectively. Computations were performed using the glm function in R (R Core Team, 2015). Categories, including the reference category, are collapsed if the number of index admissions is smaller than 50 or when there are no readmissions in the category. For more information on this see the aforementioned methodology report for the HSMR.

The results of the 2016 models are described in chapter 3 (intra-hospital model) and chapter 4 (inter-hospital model).

3. Description of the intra-hospital model 2016

3.1 Dataset

Table 3.1.1 shows the number of hospitals that were included in the intra-hospital model. All general and university hospitals could be included in both study periods (2015 and 2016). One short stay specialised hospital was excluded since it had registered only six months of complete data in 2015 and since its patients are mostly treated for oncological disease, which is excluded from the model. Due to mergers, the number of general hospitals was lower in study period 2016 compared to 2015.

3.1.1 Number of hospitals in the intra-hospital model 2016.

Study period		General hospitals[a)]	University hospitals	Selected specialised hospitals[b)]	Total hospitals
2015	Total number	75	8	3	86
	Used in model	75	8	2	85
2016	Total number	71	8	3	82
	Used in model	71	8	2	81

a) Excluding military hospital
b) One clinic for lung diseases, one cancer hospital and one eye hospital

The number of index admissions included in the intra-hospital model, the total number of identified readmissions and the unadjusted readmission rate for both study periods are listed in Table 3.1.2. Since study period 2015 consisted of admissions with a discharge date from April 1st 2015 rather than from November 1st 2014, the number of index admissions is lower compared to that in study period 2016.

3.1.2 Admissions in intra-hospital model 2016.

	2015	2016
Total number of index admissions included in model	769 000	1 334 251
Number of identified readmissions	71 317	122 078
Unadjusted readmission rate	9.3%	9.1%

3.2 Impact of the covariates on readmission rate

Appendix I shows which covariates have a statistically significant (95 percent confidence) impact on readmission rate for each of the 122 regression models (one for each diagnosis group) in the intra-hospital model. Tables 3.2.1 and 3.2.2 show the total number of significant covariates and the total Wald statistics for the 122 regression models. The tables are sorted in descending order (most important variables at the top). The first table shows in how many diagnosis groups a variable is significant in the model. The effect of variables on the predicted probabilities, and, therefore, the importance of the variables for the case mix correction performed by the models, is better measured with the Wald-statistics (shown in the second table).

The order of the variables differs somewhat in both tables, but in both tables age, urgency, sex and severity are in the top 5 of the most important variables for model estimation. For the HSMR 2016 model (Van der Laan *et al.* 2017b) this is also the case for age, urgency and severity, indicating that these variables are relevant for both predicting readmissions and in-hospital

mortality. For the intra-hospital readmission model, sex is more important than for the HSMR 2016 model, while for the HSMR 2016 model the Charlson comorbidities 9 (liver disease / severe liver disease), 17 (severe liver disease) and 16 (metastatic cancer) are more important than for the intra-hospital readmission model. Apparently severe liver disease has a higher influence on estimating in-hospital mortality than on estimating intra-hospital readmissions. The difference in importance of Charlson group 16 in both models can be explained by the fact that cancer-related main diagnoses are excluded from the readmission models, since planned readmissions for those diagnoses are frequent.

3.2.1 Statistical significance of the covariates for the 122 logistic regressions (summary), intra-hospital model 2016.

Covariate	No. of significant results	Covariate	No. of significant results
Age	103	Charlson_7	29
Urgency	77	Source of admission	28
Charlson_13	71	Charlson_5	25
Severity	68	Month of admission	19
Sex	64	Charlson_16	18
Charlson_3	62	SES	18
Charlson_1	59	Charlson_4	16
Charlson_6	57	Year	11
Charlson_2	55	Charlson_12	9
Charlson_14	55	Charlson_17	5
Charlson_10	48	Charlson_8	1
Charlson_11	36	Charlson_15	0
Charlson_9	31		

3.2.2 Wald chi-square statistics for the 122 logistic regressions, intra-hospital model 2016.

Covariate	Sum of Wald statistics	Sum of df	Covariate	Sum of Wald statistics	Sum of df
Age	13 397	1 968	Charlson_4	678	86
Urgency	8 449	121	Charlson_10	587	116
Severity	4 134	292	Charlson_11	576	80
Sex	1 799	120	Charlson_9	509	85
Charlson_13	1 568	112	Charlson_5	312	87
Source of admission	1 531	198	Charlson_7	295	85
Charlson_14	1 003	106	Year	215	122
Charlson_3	902	105	Charlson_16	200	93
Charlson_6	894	115	Charlson_12	87	54
Charlson_2	871	92	Charlson_17	65	22
Charlson_1	867	111	Charlson_8	15	5
Month of admission	751	608	Charlson_15	3	2
SES	732	541			

3.3 Model evaluation for the 122 regression analyses

Appendix III shows the Areas Under the Curve (AUCs; also known as C-statistics) for each of the 122 regression models. From these AUCs it can be concluded that most models have weak predictive power (this was also the case in the 2015 model). Of the 122 diagnosis groups, only 16 have an AUC of 0.70 or above in the 2016 intra-hospital model:

- Other non-traumatic joint disorders (diagnosis nr. 123): AUC = 0.75
- Joint disorders and dislocations; trauma-related; sprains and strains (diagnosis nr. 132): AUC = 0.74
- Fracture of upper limb (diagnosis nr. 135): AUC = 0.74
- Disorders of mouth, teeth, and jaw (diagnosis nr. 91): AUC = 0.73
- Superficial injury; contusion (diagnosis nr. 144): AUC = 0.73
- Other upper respiratory disease (diagnosis nr. 89): AUC = 0.72
- HIV infection (diagnosis nr. 5): AUC = 0.72
- Intracranial injury (diagnosis nr. 138): AUC = 0.72
- Other connective tissue disease (diagnosis nr. 126): AUC = 0.71
- Nonmalignant breast conditions (diagnosis nr. 116): AUC = 0.71
- Residual codes; unclassified (diagnosis nr. 157): AUC = 0.71
- Burns (diagnosis nr. 145): AUC = 0.71
- Open wounds of extremities (diagnosis nr. 141): AUC = 0.70
- Allergic reactions (diagnosis nr. 155): AUC = 0,70
- Lymphadenitis and gangrene (diagnosis nr. 150): AUC = 0.70
- Open wounds of head; neck; and trunk (diagnosis nr. 140): AUC = 0.70

Apparently the models that have better predictive power often concern index admissions with a main diagnosis related to injuries.

Although the predictive power of the models is generally low, the case mix correction performed by the models does remove some of the differences between the hospitals caused by population differences. However, because of the poor fit of the models, it is possible that there are still population differences remaining for which the models do not correct.

3.4 Regression coefficients

The file “coefficients intra-hospital readmission index 2016.xslx” contains the estimated regression coefficients (columns ‘Estimate’) for each of the 122 logistic regressions as well as their standard errors (columns ‘Std. Err.’). 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. 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 diagnosis group (i.e. if there was only one category with ≥50 admissions and ≥1 readmission), the variable was dropped from the model and all associated coefficients were set to zero. The significance of each of the coefficients is shown in Appendix I.

3.5 Limitations

The readmission indicator has largely the same limitations as the HSMR. Below we will address some issues that are specific to the readmission indicator.

- In principle all readmissions are included in the model: planned and unplanned; related and not related to the index admission. Ideally only unplanned readmissions should be included. However, these are not registered as such in the LBZ. The LBZ contains the variable urgency (acute versus not acute). An admission is registered 'acute' if care is needed within 24 hours and therefore does not seem to reflect the difference between planned and unplanned readmissions. To avoid the inclusion of planned readmissions, some diagnosis groups where planned readmissions are likely (for example the various groups concerning cancer) are excluded as index and readmissions. Also diagnoses that are likely planned readmissions (for example follow-up care and rehabilitation) are excluded as potential readmissions. Furthermore, in the present model (planned) transfers are excluded as readmissions. However, there will still be planned readmissions remaining in the dataset.
- Unlike with the HSMR, Statistics Netherlands does not provide readmission ratios for 2016, based on the model of 2016. DHD will use the estimated models to calculate the ratios using hospital data from 2017. This means that the models are applied to a different year than that on which they were estimated. As was shown for the readmission model 2015 (Van der Laan *et al.* 2017a), this results in a bias and extra variance. Fortunately, the bias can be estimated and the overall average of the ratio can be presented to the hospitals.
- It is difficult to predict readmissions using the variables present in the models: the models explain only a very small part of the observed variation. This makes it more likely that there are unobserved population differences that are not corrected for, that influence the readmission probability. This means that some of the differences in the current readmission ratio can be caused by unobserved population differences.
- The model described in this chapter identifies intra-hospital readmissions only and readmissions that occur in another hospital are not identified. As a result, for hospitals where patients are often readmitted in another hospital, the indicator could underestimate the readmission ratio and vice versa. This particular problem is solved in the inter-hospital model, of which the results are described in the next chapter.

4. Description of the inter-hospital model 2016

4.1 Dataset

The number of included hospitals was the same for both the intra- and the inter-hospital model for both study periods (see 3.1). The number of index admissions included in the inter-hospital readmission model, the total number of identified readmissions and the unadjusted readmission rates for both study periods are listed in Table 4.1.1. Since study period 2015 consisted of admissions with a discharge date from April 1st 2015 rather than from November 1st 2014, the number of index admissions is lower compared to that in study period 2016. For both study periods, the unadjusted readmission rate is 1% higher in the inter-hospital model compared to that in the intra-hospital model, due to the additional identification of readmissions in other hospitals.

4.1.1 Admissions in inter-hospital model 2016.

	2015	2016
Total number of index admissions included in model	769 000	1 334 51
Number of identified readmissions	78 894	134 691
Unadjusted readmission rate	10.3%	10.1%

4.2 Impact of the covariates on readmission rate

Appendix II shows which covariates have a statistically significant (95 percent confidence) impact on readmission rate for each of the 122 regression models (one for each diagnosis group) in the inter-hospital model. Tables 4.2.1 and 4.2.2 show the total number of significant covariates and the total Wald statistics for the 122 regression models. The tables are sorted in descending order (most important variables at the top). The first table shows in how many diagnosis groups a variable is significant in the inter-hospital model. The effect of variables on the predicted probabilities, and, therefore, the importance of the variables for the case mix correction performed by the models, is better measured with the Wald-statistics (shown in the second table).

The order of the variables differs somewhat in both tables, but in both tables, as was observed for the intra-hospital model, age, urgency, sex and severity are in the top 5 of the most important variables for model estimation. Furthermore, the ranking of the variables is comparable to that of the intra-hospital model and as a result, the differences compared to the HSMR model 2016 are similar for both the intra- and the inter-hospital model (see 3.2).

4.2.1 Statistical significance of the covariates for the 122 logistic regressions (summary), inter-hospital model 2016.

Covariate	No. of significant results	Covariate	No. of significant results
Age	101	Charlson_7	27
Urgency	76	Source of admission	24
Severity	73	Charlson_5	23
Charlson_13	72	SES	19
Sex	61	Charlson_4	18
Charlson_1	61	Charlson_16	15
Charlson_3	60	Month of admission	13
Charlson_2	59	Charlson_12	12
Charlson_6	57	Year	11
Charlson_14	52	Charlson_17	6
Charlson_10	48	Charlson_8	1
Charlson_11	34	Charlson_15	0
Charlson_9	31		

4.2.2 Wald chi-square statistics for the 122 logistic regressions, inter-hospital model 2016.

Covariate	Sum of Wald statistics	Sum of df	Covariate	Sum of Wald statistics	Sum of df
Age	13 870	1968	SES	721	541
Urgency	8 965	121	Charlson_9	625	85
Severity	4 502	292	Charlson_10	622	116
Sex	1 999	120	Charlson_11	598	80
Source of admission	1 778	198	Charlson_5	341	87
Charlson_13	1 680	112	Charlson_7	298	85
Charlson_2	986	92	Year	212	122
Charlson_3	962	105	Charlson_16	181	93
Charlson_1	944	111	Charlson_12	98	54
Charlson_6	935	115	Charlson_17	75	22
Charlson_14	844	106	Charlson_8	14	5
Charlson_4	743	86	Charlson_15	2	2
Month of admission	740	608			

4.3 Model evaluation for the 122 regression analyses

Appendix III shows the Areas Under the Curve (AUCs; also known as C-statistics) for each of the 122 regression models. From these AUCs it can be concluded that most models have weak predictive power. Of the 122 diagnosis groups, only 13 have an AUC of 0.70 or above, which is slightly lower than observed for the intra-hospital model (17 diagnosis groups).

4.4 Regression coefficients

The file “coefficients inter-hospital readmission index 2016.xslx” contains the estimated regression coefficients (columns ‘Estimate’) for each of the 122 logistic regressions as well as their standard errors (columns ‘Std. Err.’). 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. 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 diagnosis group (i.e. if there was only one category with ≥50 admissions and ≥1 readmission), the variable was dropped from the model and all associated coefficients were set to zero. The significance of each of the coefficients is shown in Appendix II.

5. Additional investigations for the models of 2016

As was mentioned in section 2.1, there have been some changes in the methods compared to last year, which are primarily:

1. Two models are published: one that only considers intra-hospital readmissions and one that also considers inter-hospital readmission
2. Transfers are now excluded in the models, i.e. admissions that are followed by a transfer (to another hospital) cannot have a readmission and transfers cannot be readmissions. This also applies to the intra-hospital model.

The effects of these changes are investigated in this chapter. Furthermore, section 5.3 investigates the effect of removing index admissions followed by a transfer from the nominator of the readmission ratio. Finally, it is investigated whether 'year' should be included as covariate in the model.

For these investigations we used the dataset of index admissions from April 1st 2015 up to October 31st 2015 ('study period 2015') and from November 1st 2015 up to October 31st November 2016 ('study period 2016').

In results where the readmission ratios of hospitals are compared (such as tables 5.1.3 and 5.2.3), two hospitals with less than 100 readmissions have been omitted. In those tables the total number of hospitals covering both study periods (86) exceeds the number presented in 3.1 (85 in study period 2015 and 81 in study period 2016), due to merging hospitals: some hospitals that were analysed as separate entities in 2015 had merged in 2016 to a hospital with a new registration number. Such hospitals count as three units in the overall results (covering both years), rather than two.

5.1 Effect of adding inter-hospital readmissions

In this investigation we compare the intra-hospital model with the inter-hospital model. For the intra-hospital model we use the same method as last year (except for using another person identifier). For the inter-hospital model readmissions in both the same as another hospital are included, but as was mentioned in section 2.3.7, transfers are not considered readmissions. In the intra-hospital model used in this investigation no modifications are done in relation to transfers (so transfers can be readmissions), comparable to the method used last year.

Figure 5.1.1 shows the fraction of readmissions found in the two methods, for each of the diagnosis groups. In general the number of readmissions increases when inter-hospital admissions are taken into account. However, there are also a few diagnosis groups where the fraction decreases. This is possible because transfers are not considered readmissions in the inter-hospital model. Therefore, an admission in hospital A, followed by a transfer to hospital B, followed by a transfer back to A, does not result in any readmission in the case of the inter-hospital readmission ratio, but it does result in a readmission in the case the of the intra-hospital readmission ratio (where the third admission is a readmission of the first). The diagnosis groups for which this happens are (diagnosis group number is mentioned between brackets):

- Acute myocardial infarction (62)
- Short gestation; low birth weight; and fetal growth retardation (129)
- Intrauterine hypoxia, perinatal asphyxia, and jaundice (130)

- Cardiac arrest and ventricular fibrillation (69)
- Acute bronchitis (81)
- Respiratory failure; insufficiency; arrest (86)
- Meningitis, encephalitis, and other central nervous system infections (51)
- Asthma (83)
- Diseases of white blood cells (46)
- Tuberculosis (1)
- Bacterial infection; unspecified site (3)
- Shock (151)
- Coronary atherosclerosis and other heart disease (63)
- Peri-, endo-, myocarditis, and cardiomyopathy (60)
- Mycoses (4)

These are diagnosis groups where transfers to and from another hospital ('A-B-A' transfers) are relatively frequent.

5.1.1 The fraction of readmissions for the inter-hospital readmission ratio and the intra-hospital readmission ratio for each of the diagnosis groups.

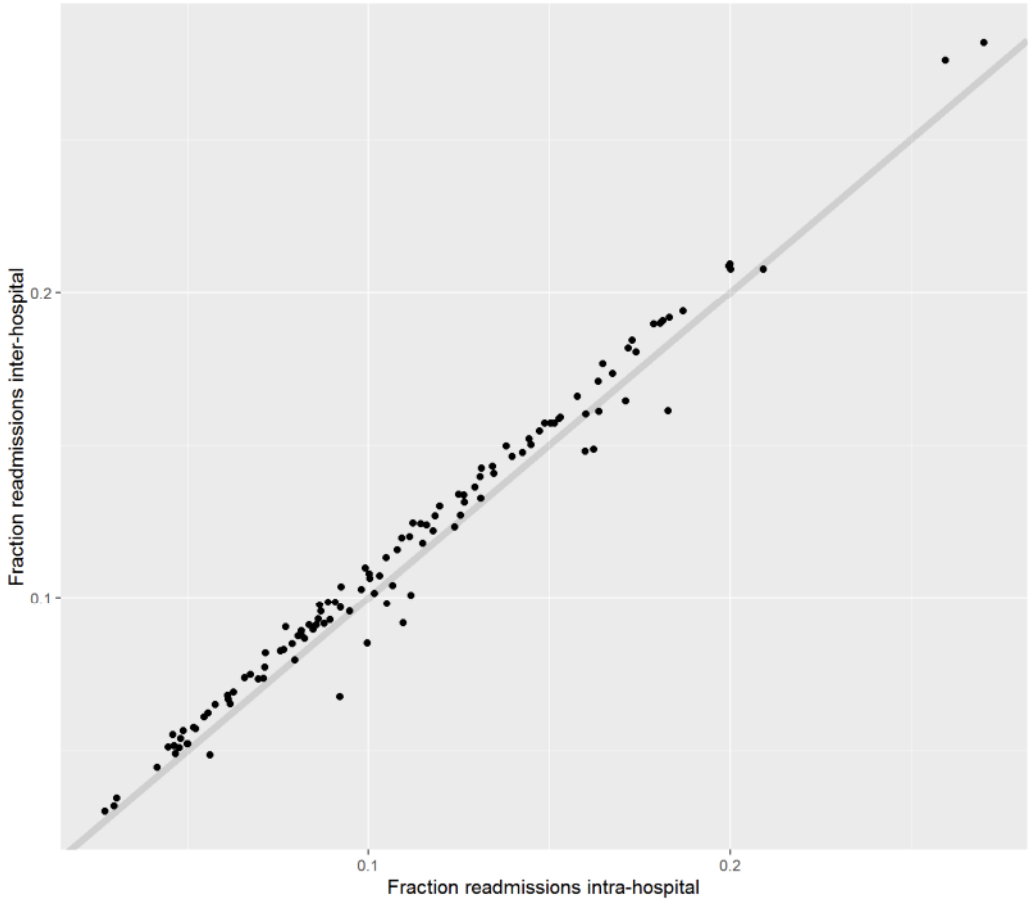


Figure 5.1.2 compares the predictive powers of both models for each of the 122 diagnosis groups. The differences are small: the overall AUC is 0.689 in case of the intra-hospital model and 0.687 in case of the inter-hospital model.

5.1.2 The Area Under the Curve (AUC) per diagnosis group for the inter-hospital readmission ratio and the intra-hospital readmission ratio for each of the diagnosis groups.

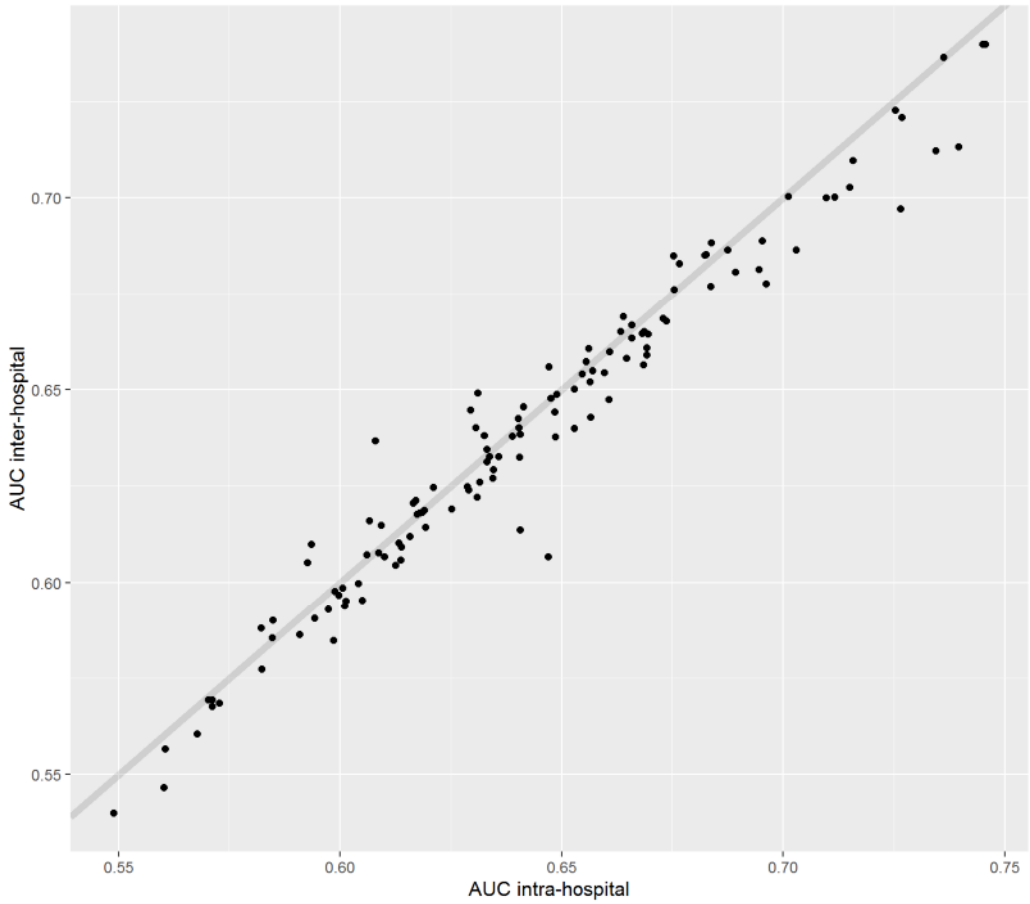


Table 5.1.3 shows the number of hospitals with either significantly low or high readmission ratios according to both methods. The number of hospitals with a ratio differing significantly from 100 is for both methods approximately the same: 54 for the intra-hospital and 53 for inter-hospital ratio. However, when comparing the two methods, the significance of the ratio changes in 21 hospitals. Especially the hospitals with a significantly low ratio differ between the two methods: 9 hospitals with a significantly low ratio in the intra-hospital model have a non-significant ratio in the inter-hospital model while 9 hospitals with a significantly low ratio in the inter-hospital model have a non-significant ratio in the intra-hospital model. The average absolute difference between the two ratios of the models is 3.1 points. The spread in the ratios is lower for the inter-hospital ratio: the standard deviation is 8.7 compared to 9.7 for the other method.

5.1.3 Number of hospitals with a significantly (95% confidence) high or low readmission ratio for the inter-hospital model and the intra-hospital model.

	Inter-hospital			
Intra-hospital	**Low**	**Non-significant**	**High**	**Total**
Low	25	9	0	**34**
Non-significant	9	22	1	**32**
High	0	2	18	**20**
Total	**34**	**33**	**19**	**86**

5.2 Effect of transfers in intra-hospital model

As was mentioned in the previous paragraph, for some diagnosis groups it is possible that the number of readmissions is lower when inter-hospital readmissions are taken into account. This is possible because transfers are not considered readmissions in the inter-hospital model, whereas in the intra-hospital model they were. Therefore, an admission in hospital A, followed by a transfer to hospital B, followed by a transfer back to A, does not result in any readmission in the case of the inter-hospital model, but it does result in a readmission in the case the of the intra-hospital model (where in this situation of 'to and fro' transfers ('A-B-A'), the third admission is a readmission of the first). When the number of these 'A-B-A' transfers exceeds the number of additionally identified inter-hospital readmissions, the number of readmissions found in the intra-hospital model is higher than in the inter-hospital model. As it is questionable whether these admissions should be regarded as readmissions, the effect of not counting 'to and fro' transfers as readmissions in the intra-hospital model was investigated. As was explained in 2.3.7, the following rules were used for excluding transfers:

- An admission that is followed by a transfer, cannot have a readmission.
- A transfer cannot be a readmission.

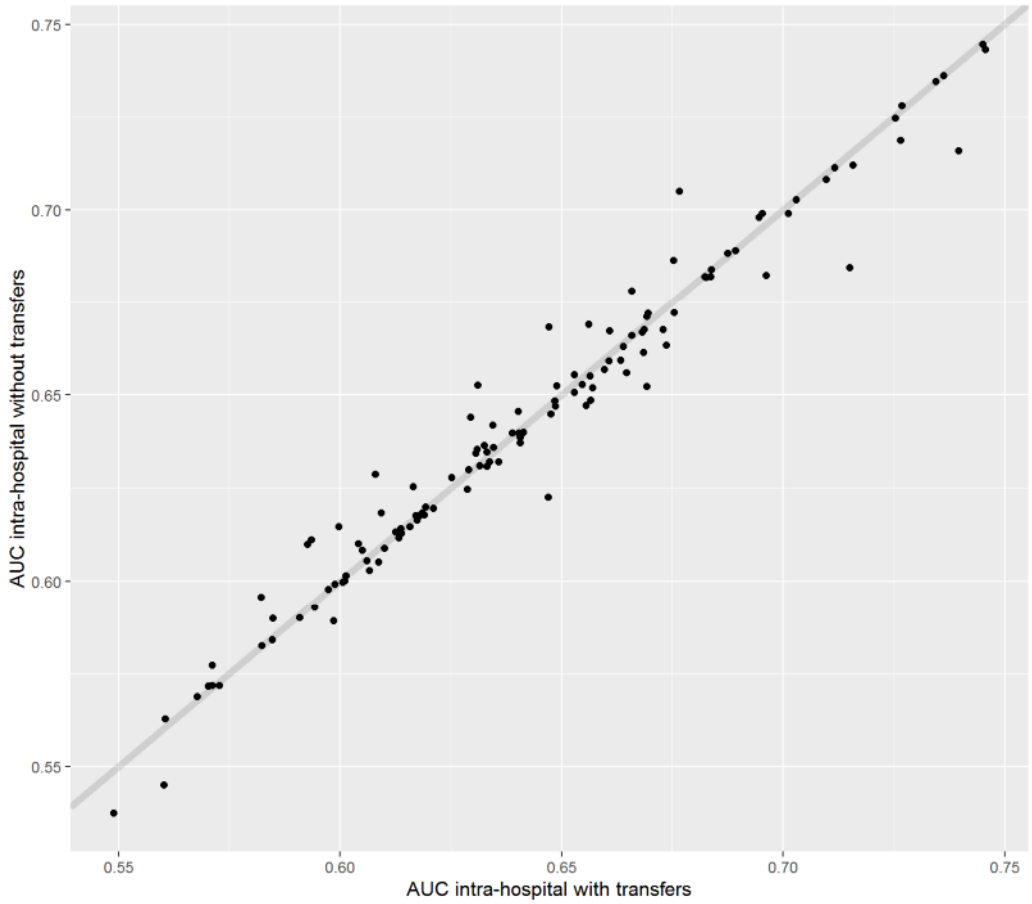
Table 5.2.1 shows that the fraction of readmissions in the intra-hospital model decreases by approximately 5 percent when transfers from another hospital are not counted as readmissions ('excl. transfers').

5.2.1 Number of admission and readmissions for the two years in the models for the intra-hospital readmission ratio including and excluding transfers.

	Year	Number of admissions	Number of readmissions	Fraction of readmissions
Intra-hospital incl. transfers	2015	769 000	74 977	9.75%
	2016	1 334 251	128 568	9.64%
Intra-hospital excl. transfers	2015	769 000	71 317	9.27%
	2016	1 334 251	122 078	9.15%

Figure 5.2.2 shows that omitting the transfers has little effect on the model fit (the overall AUCs are 0.689 and 0.692 for the models including and excluding transfers respectively). Table 5.2.2 shows that there are some hospitals (12) where the significance of the ratio changes. Most markedly there are 7 hospitals that did not have a significantly low ratio when transfers are included as readmission, but that do have a significantly low ratio when the transfers are excluded. Overall the number of hospitals with a significant ratio increases from 54 to 58.

5.2.2 The Area Under the Curve (AUC) per diagnosis group for the intra-hospital readmission ratio with and without transfers.



5.2.3 Number of hospitals with a significantly (95% confidence) high or low readmission ratio for the intra-hospital model with and without transfers.

Intra-hospital	Intra-hospital without transfers			
with transfers	**Low**	**Non-significant**	**High**	**Total**
Low	32	2	0	**34**
Non-significant	7	24	1	**32**
High	0	2	18	**20**
Total	**39**	**28**	**19**	**86**

Table 5.2.4 shows the diagnosis groups that are most strongly affected by excluding transfers. In some groups the change can be substantial: over 20% reduction in the number of readmissions (i.e. over 20% of the readmissions are transfers). Most of these groups (9/12) are also in the list in the previous paragraph. As mentioned previously (see table 5.2.1), the total reduction in the number of readmissions (all diagnosis groups) is 5%.

5.2.4 Top 12 diagnosis groups with the largest change in the number of readmissions when excluding transfers from the intra-hospital model.

Diagnosis group (number and name)		Number of index admissions	Number of readmissions	Number of readmissions after removal of transfers	Percentage change
69	Cardiac arrest and ventricular fibrillation	3 268	301	191	37%
1	Tuberculosis	676	108	78	28%
130	Intrauterine hypoxia, perinatal asphyxia, and jaundice	20 952	1 177	890	24%
62	Acute myocardial infarction	51 064	5 597	4 315	23%
129	Short gestation; low birth weight; and fetal growth retardation	24 200	2 411	1 878	22%
127	Cardiac and circulatory congenital anomalies	3 828	458	357	22%
86	Respiratory failure; insufficiency; arrest	2 282	417	328	21%
59	Heart valve disorders	15 674	1 965	1 552	21%
51	Meningitis, encephalitis, and other central nervous system infections	3 793	424	340	20%
138	Intracranial injury	18 573	930	758	18%
151	Shock	444	72	59	18%
63	Coronary atherosclerosis and other heart disease	61 255	6 229	5 134	18%

The diagnosis groups that are affected most by excluding transfers contain diagnoses for which transfers to other (more specialised) hospitals are likely to occur. For example, patients with several types of heart disease might be transferred for coronary interventions or for ICD (implantable cardioverter defibrillator) placement to specialised heart centres, while newborns with low birth weight might be transferred to a hospital with a NICU (neonatal intensive care unit).

5.3 Effect of removing index admissions followed by a transfer

In case of inter-hospital readmissions, and also in case of not counting transfers as readmission in the intra-hospital model, index admissions followed by a transfer cannot be followed by a readmission. This means that hospitals with a large number of transfers are more likely to have relatively few readmissions. Therefore, it might be more fair to remove index admissions followed by a transfer from the model. Figure 5.3.1 shows the effect of removing those index admissions on the model fit for the inter-hospital model. The effect is small. The overall AUC increases from 0.687 to 0.689 when index admissions followed by a transfer are removed.

5.3.1 The Area Under the Curve (AUC) per diagnosis group for the inter-hospital readmission ratio with and without including index admission followed by a transfer.

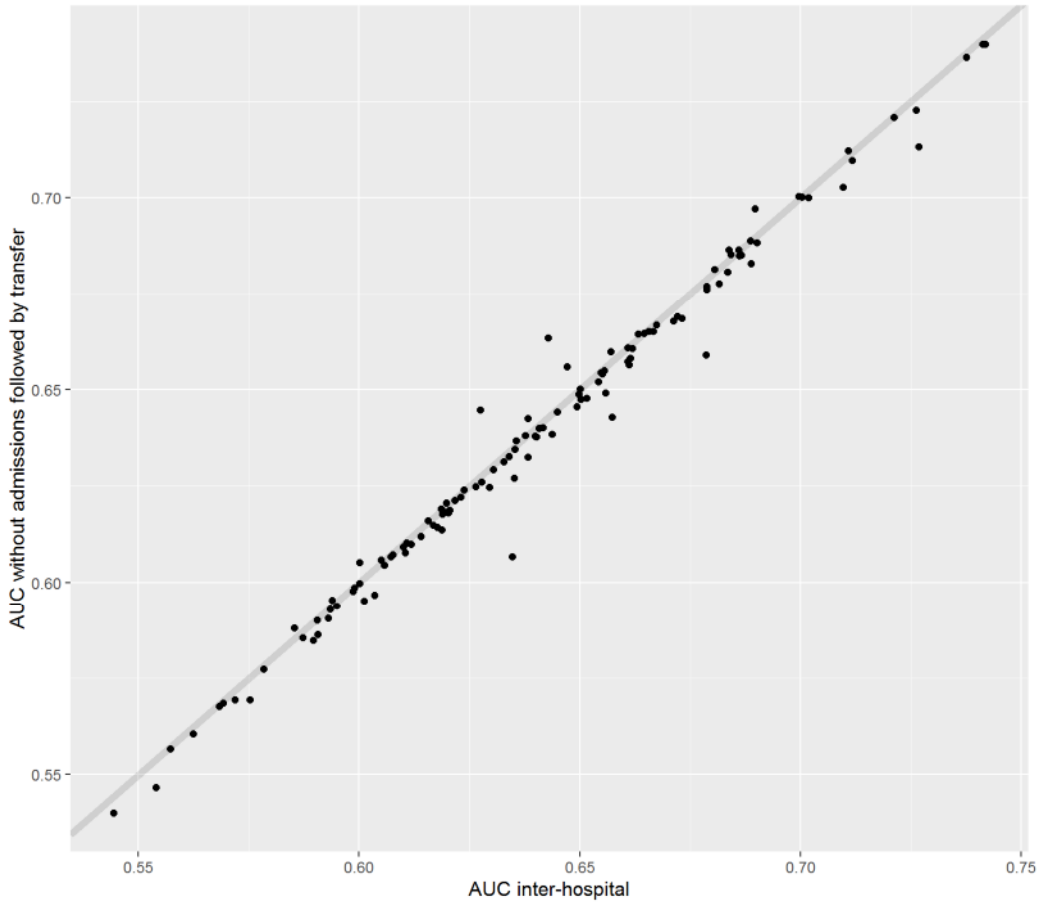


Table 5.3.2 shows the effect of removing those index admissions on the number of hospitals with significantly high or low ratios. Eleven hospitals have a change in the significance of the ratio.

5.3.2 Number of hospitals with a significantly (95% confidence) high or low readmission ratio for the inter-hospital model with and without including index admission followed by a transfer.

Inter- hospital <u>with</u> index admissions followed by a transfer	**Inter-hospital <u>without</u> index admissions followed by a transfer**			
	Low	**Non-significant**	**High**	**Total**
Low	30	4	0	**34**
Non-significant	2	28	3	**33**
High	0	2	17	**19**
Total	**32**	**34**	**20**	**86**

Table 5.3.3 shows the diagnosis groups that are affected most when removing index admissions followed by a transfer. These are largely the same groups as found earlier (11/12). Overall the number of index admissions decreases by 3%.

5.3.3 The top-12 diagnosis groups with the largest decrease in the number of index admissions after removal of index admissions followed by a transfer.

Diagnosis group		Number of index admissions	Index admissions without transfer	Percentage change
69	Cardiac arrest and ventricular fibrillation	3 268	2 513	23%
62	Acute myocardial infarction	51 064	42 209	17%
151	Shock	444	371	16%
1	Tuberculosis	676	572	15%
86	Respiratory failure; insufficiency; arrest	2 282	1 951	15%
129	Short gestation; low birth weight; and fetal growth retardation	24 200	20 793	14%
5	HIV infection	459	404	12%
127	Cardiac and circulatory congenital anomalies	3 828	3 390	11%
59	Heart valve disorders	15 674	14 089	10%
51	Meningitis, encephalitis, and other central nervous system infections	3 793	3 412	10%
63	Coronary atherosclerosis and other heart disease	61 255	55 246	10%
60	Peri-, endo-, myocarditis, and cardiomyopathy	8 098	7 421	8%

5.4 Inclusion of 'year' in the models

The model is based on index admissions from April 1st 2015 up to October 31st 2015 ('year'=2015) and from November 1st 2015 up to October 31st November 2016 ('year'=2016). Since the models now include data from multiple years, it is of interest to see whether the inclusion of a coefficient for 'year' in the model (as has been implemented now) is necessary or not. This coefficient should correct for changes in the raw readmission fraction over time. In paragraphs 3.1 and 4.1 we described the crude readmission rates for both the intra- and the inter-hospital model, which from 2015 to 2016 changed from 9.3% to 9.1% and from 10.3% to 10.1% respectively. This decrease is significant in both cases (p-value < 0.01). Therefore, it can be concluded that 'year' should indeed be included in the models.

5.5 Conclusion of the investigations

Four models have been considered:

1. Intra-hospital: this is the method counting readmissions within hospitals, comparable to the method used for the 2015 model, with the difference that the identification of the patients is now done using the personal identifier instead of the hospital-specific patient ID.
2. Inter-hospital: here readmissions within and between hospitals are included. Transfers between hospitals are not counted as readmissions.
3. Intra-hospital excluding transfers: here readmissions within hospitals are counted, but with the restriction that transfers cannot be readmissions and index admissions followed by a transfer cannot have a readmission.
4. Inter-hospital with removal of index admissions followed by a transfer. Transfers between hospitals are not counted as readmissions.

In all cases the quality of the models, as estimated by the Area Under the Curve, are approximately equal. This means that for none of the methods the models are better able to predict readmission. By excluding transfers, some of the planned readmissions are excluded. Planned readmissions are probably easier to predict than unplanned readmissions. However, we do not see a deterioration of the model fit. The conclusion is that readmissions are generally difficult to predict regardless of how they are defined. However, as reported earlier (Van der Laan et al. 2017a), correcting for population differences does lead to a better readmission index. Although the quality of the models is not influenced, the models do differ in their predictions, resulting in shifts of the readmission ratios per hospital. In all cases, a substantial number of hospitals shift from not having a significantly low or high ratio to having one and vice versa. The largest number of differences in significance of the ratio occur when the intra-hospital model and the inter-hospital model are compared.

It was decided to publish both the intra-hospital model (method 3) and the inter-hospital model (method 2). In section 5.1, we identified diagnosis groups where transfers from a hospital A to a hospital B, are sometimes followed by a transfer back to A. For the intra-hospital model it was decided to remove all of the above-mentioned transfers (from all diagnosis groups) from the model (method 3) as this removes some of the noise from the models, since these can be considered as planned readmissions, which are not of interest when the readmission ratio is used as indicator of quality of care.

5.6 Comparison of final models

The two models that will be published have not yet been compared directly in previous paragraphs. Therefore, they will be compared in this section.

The total number of index admissions in 2015 and 2016 is 2 103 251. For the intra-hospital readmission ratio there are 193 395 readmissions (9.2%), for the inter-hospital readmission ratio there are 213 585 readmissions (10.2%). In the inter-hospital model the number of readmissions therefore increases with 10.4%, and the raw readmission rate increased by one percent point.

Figure 5.6.1 shows the AUC for each of the published models for the individual diagnosis groups. For most diagnosis groups the AUC has decreased somewhat when additionally identifying inter-hospital readmissions. Apparently, inter-hospital readmissions can be predicted somewhat less well than intra-hospital readmissions in these groups. However, there are also some diagnosis groups for which the AUC has increased. The overall AUC for both methods is nearly the same (0.692 for the intra-hospital model and 0.687 for the inter-hospital model), so in general the differences in the quality of the predictions between the two models are small. The fact that most individual AUCs are slightly lower for the inter-hospital model while the overall AUC is the same for both models, is caused by the fact that the overall AUC also takes into account the differences in readmission probability between the diagnosis groups. These differences are easier to predict, resulting in a higher overall AUC for both models.

5.6.1 The Area Under the Curve (AUC) per diagnosis group for the inter-hospital readmission ratio compared to the intra-hospital readmission ratio excluding transfers.

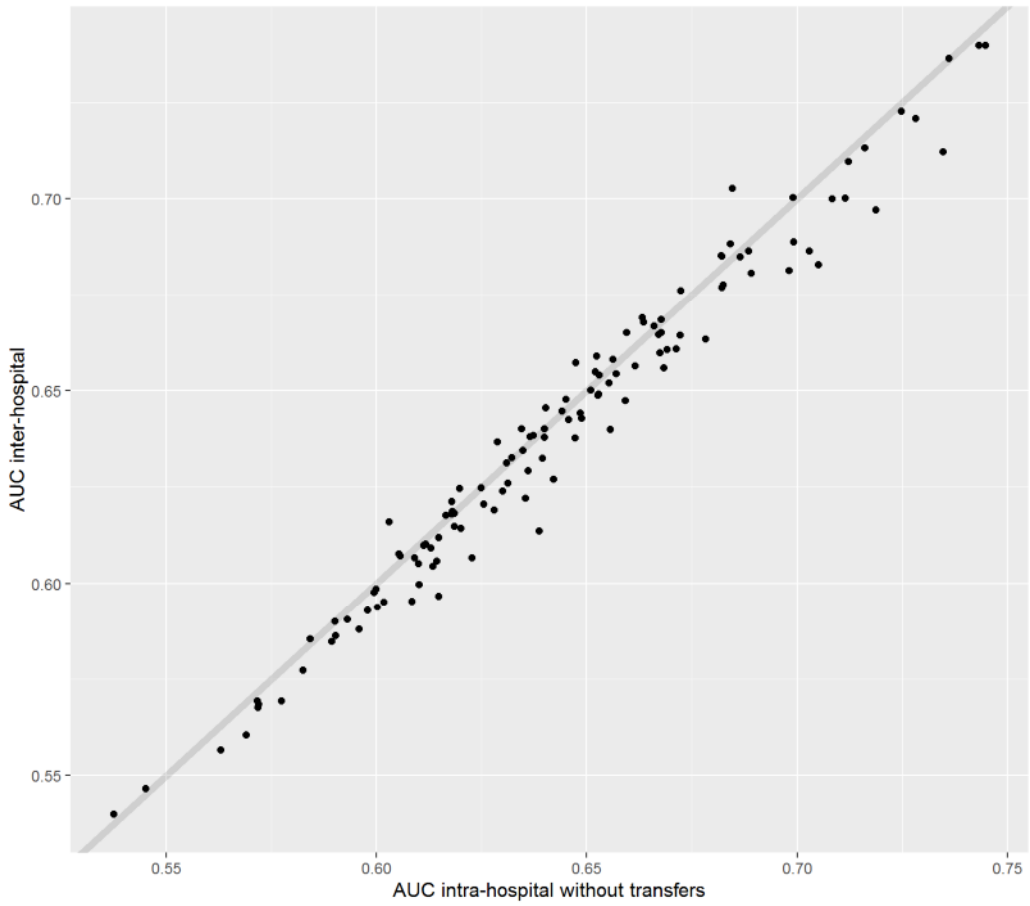


Table 5.6.2 shows the differences in significance of the readmission ratios for the two methods. When inter-hospital readmissions are included, there are five hospitals less with a significant readmission ratio (53 instead of 58). As seen earlier, the differences in significance are mainly observed for lower readmission ratios. Overall the significance of the ratio changes in 19 of the 86 hospitals. So, although the differences in model fit are small, different sets of hospitals are found for which the readmission ratios are significantly different from 100.

The average absolute difference between the two ratios of the models is 3.7 points. The spread in the ratios is lower for the inter-hospital ratio: the standard deviation is 8.7 instead of 9.7.

5.6.2 Number of hospitals with a significantly (95% confidence) high or low readmission ratio for the inter-hospital model and the intra-hospital model without transfers.

	Intra-hospital without transfers			
Inter- hospital	**Low**	**Non-significant**	**High**	**Total**
Low	30	4	0	**34**
Non-significant	9	21	3	**33**
High	0	3	16	**19**
Total	**39**	**28**	**19**	**86**

The choice of applying the intra-hospital model or the inter-hospital model depends on what definition of readmission is considered to be most relevant for identifying readmissions that can be indicative for (suboptimal) quality of care. The inter-hospital model gives a complete picture of all readmissions and may for this reason be preferred, but it is not known whether the additionally identified readmissions (in another hospital) are as likely to be related to the index admission than in the case of intra-hospital readmissions. This can also differ per hospital or per diagnosis group. Furthermore, practical considerations can also be taken into account. A practical disadvantage of the inter-hospital ratio is that hospitals need patient information from other hospitals to calculate the ratios and to study the files of the patients with readmissions. For this reason DHD uses the intra-hospital model in their regular hospital indicators reports.

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Appendix I: Results of the logistic regressions (intra-hospital model)

Statistical significance (95% confidence) of the covariates for the 122 logistic regressions (1=significant; 0=non-significant; "-"=variable dropped because all categories are collapsed, due to < 50 admissions or no readmissions in all but one category).

Diagnosis group	Sex	Age	Urgency	Severity	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	Source admission	Year
1	0	1	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
2	1	1	0	0	0	0	1	1	0	0	1	-	1	1	1	0	1	1	-	0	-	0	0	0	0
3	0	0	0	0	0	0	0	1	0	0	0	-	1	0	0	-	1	1	-	0	-	0	0	0	0
4	0	0	0	0	-	-	-	-	-	0	-	-	-	0	-	-	1	1	-	0	-	0	0	-	0
5	0	0	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	0	0	0	1
6	0	1	1	1	0	1	0	1	0	0	0	-	1	0	0	-	0	1	-	0	0	0	1	0	0
37	1	1	1	1	0	1	1	0	0	1	1	-	0	1	0	0	1	0	-	0	-	0	0	0	0
38	1	1	1	0	1	1	1	0	0	0	0	-	0	0	0	-	1	0	-	0	-	0	0	0	0
39	0	1	1	0	0	1	0	0	0	1	0	-	0	0	1	-	1	0	-	0	-	0	0	0	0
40	1	1	0	1	1	1	1	0	0	0	0	-	0	1	1	-	1	0	-	0	-	0	0	0	0
41	1	1	1	1	0	0	0	0	1	0	0	-	0	0	0	0	1	1	-	0	-	0	0	0	0
42	1	1	1	1	0	0	0	0	1	1	0	-	1	0	0	0	0	1	-	1	0	0	0	0	0
43	0	0	0	0	-	-	-	-	-	0	-	-	0	0	-	-	-	-	-	-	-	0	0	-	0
44	0	1	1	0	0	0	0	0	1	0	0	-	0	0	-	-	0	1	-	0	-	1	0	0	0
45	1	1	1	1	1	1	0	0	1	1	1	0	1	0	1	0	1	0	-	0	1	0	0	0	0
46	0	1	0	-	0	-	0	-	-	0	-	-	-	0	-	-	0	0	-	1	-	0	0	0	0
51	0	1	1	1	0	-	-	0	-	0	-	-	-	0	-	0	0	0	-	-	-	0	0	1	0
52	0	0	0	0	0	-	-	-	0	0	-	-	-	0	-	-	0	-	-	-	-	0	0	0	0
53	0	1	1	1	0	-	0	0	0	1	-	-	-	0	-	0	0	1	-	-	-	0	0	1	0
54	0	0	0	0	0	-	0	1	-	1	-	-	-	0	-	0	0	0	-	0	-	0	0	0	0
55	0	1	1	1	1	0	1	0	0	1	0	-	0	0	0	0	0	0	-	0	-	1	0	0	0
56	1	1	0	0	0	-	0	0	0	0	-	-	0	1	-	-	1	0	-	0	-	0	0	0	0
57	1	1	1	1	1	1	1	1	0	1	1	-	0	1	0	0	1	1	-	1	-	0	0	0	1
58	1	1	1	1	1	1	1	1	0	1	1	-	1	1	1	0	1	0	-	0	-	1	0	0	0
59	0	1	1	0	0	1	1	0	0	0	0	-	0	1	1	-	1	0	-	1	-	0	0	1	1
60	0	1	1	1	1	1	0	0	-	0	1	-	0	0	0	-	1	1	-	1	-	0	1	1	0
61	0	0	0	1	1	1	1	0	-	0	1	-	0	0	1	-	1	0	-	-	-	0	0	0	1
62	1	1	1	1	1	1	1	0	1	1	1	-	0	1	1	0	1	1	-	0	-	1	0	1	1
63	1	1	1	0	1	1	1	1	0	1	1	-	1	1	1	0	1	0	-	0	-	0	0	1	0
64	1	1	0	-	1	1	1	0	0	1	0	-	1	1	1	0	1	1	-	1	-	0	0	0	0
65	0	1	1	1	1	1	0	0	0	1	1	-	0	0	0	0	1	1	-	1	-	0	1	1	0
66	0	0	0	0	0	0	1	-	-	0	-	-	-	0	-	-	0	-	-	-	-	1	0	1	1
67	0	1	1	0	1	0	1	0	0	1	0	-	-	0	1	-	1	0	-	-	-	0	0	0	0
68	1	1	1	1	1	1	1	0	0	1	1	-	0	1	1	0	1	1	-	0	-	0	0	0	0
69	1	1	1	0	0	1	0	0	-	0	-	-	-	0	-	-	1	0	-	-	-	0	0	0	0

Diagnosis group	Sex	Age	Urgency	Severity	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	Source admission	Year
70	1	1	1	0	1	1	1	0	1	1	0	-	0	1	1	0	1	0	-	1	0	1	0	1	1
71	1	1	0	1	1	1	1	1	1	1	1	-	1	1	1	0	1	0	-	0	-	0	0	1	1
72	1	1	0	0	1	0	1	1	0	0	0	-	0	0	1	0	1	1	-	1	-	0	0	1	0
73	1	1	1	1	1	1	1	0	1	1	1	-	0	1	1	0	1	0	-	0	-	0	1	0	0
74	1	0	1	1	1	0	0	0	0	1	0	-	0	0	0	0	0	0	-	0	-	0	0	1	0
75	1	1	1	1	1	1	1	0	0	0	1	-	-	0	1	-	1	0	-	0	-	0	0	0	0
76	1	1	1	1	1	1	1	0	0	1	0	-	0	1	1	0	1	0	-	0	-	0	0	0	0
77	1	1	1	1	0	0	1	0	0	1	0	-	1	1	0	-	0	1	-	0	0	0	0	0	0
78	1	1	0	1	1	1	1	0	1	1	1	-	0	1	1	1	1	1	0	1	0	0	0	1	0
79	1	1	0	0	1	1	1	0	0	1	1	-	0	0	-	-	1	1	-	0	-	0	0	0	0
80	1	1	1	0	1	1	1	1	0	1	0	-	0	0	1	0	0	1	-	1	-	0	0	0	0
81	1	1	0	0	0	0	0	-	0	1	0	-	-	0	-	-	0	1	-	0	-	0	0	1	0
82	1	1	1	1	1	1	1	0	1	0	0	-	0	1	1	1	1	1	-	1	-	1	1	1	0
83	1	1	0	-	1	1	0	-	-	1	1	-	-	1	0	-	0	1	-	-	-	0	0	0	0
84	1	0	0	-	1	0	0	0	0	0	-	-	0	0	-	0	0	1	-	0	-	0	0	1	0
85	0	1	1	1	0	1	0	0	0	0	0	-	1	0	0	-	0	0	-	0	-	0	0	1	0
86	0	1	0	0	0	0	0	0	-	1	-	-	0	1	-	-	0	0	-	0	-	0	0	0	0
87	0	0	0	0	0	-	-	-	-	0	-	-	-	0	-	-	-	0	-	0	-	0	0	-	0
88	0	1	0	1	1	1	0	0	1	1	1	-	0	1	0	0	1	1	-	0	-	0	1	1	0
89	0	1	1	1	1	1	0	0	1	1	0	-	0	1	1	0	1	1	-	0	-	1	0	0	0
90	0	1	1	1	0	1	1	0	0	1	1	-	1	1	0	1	1	1	-	0	0	0	1	0	0
91	0	1	1	1	0	-	-	-	-	0	-	-	-	0	-	-	0	1	-	0	-	1	1	1	0
92	0	1	1	1	0	0	0	1	0	0	0	0	1	0	0	-	1	1	-	0	0	0	0	0	0
93	0	0	0	0	0	-	1	-	-	1	-	-	-	0	-	-	0	1	-	-	-	0	0	-	0
94	0	1	0	1	0	0	1	-	-	0	0	0	1	1	0	-	0	1	-	0	1	0	0	0	0
95	0	1	1	-	1	-	0	-	-	1	0	-	0	1	-	-	0	0	-	-	-	0	1	0	0
96	0	0	0	0	0	-	0	-	-	0	-	-	1	0	-	-	1	0	-	0	0	0	0	0	0
97	1	1	1	1	1	0	1	0	0	1	0	-	1	1	1	-	1	0	-	0	-	0	0	0	0
98	0	1	1	-	0	-	0	-	-	0	-	-	0	0	-	-	0	0	-	-	-	0	0	0	0
99	0	1	0	1	0	1	1	0	1	0	0	-	0	0	0	0	0	0	-	0	-	0	0	0	0
100	0	1	1	1	1	0	0	0	0	1	0	-	0	1	0	-	1	0	-	0	-	0	0	1	0
101	0	1	1	1	0	-	0	-	0	0	1	-	-	0	-	-	0	1	-	0	-	0	0	0	0
102	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	1	1	1	-	1	1	0	0	0	0
103	0	1	1	1	0	-	0	-	-	0	-	-	1	1	-	-	0	0	-	-	0	0	1	1	0
104	1	1	1	1	1	1	1	0	0	0	0	-	1	1	0	-	0	0	-	1	0	0	0	0	0
105	1	1	1	1	0	0	0	0	0	0	0	-	0	0	0	-	1	0	-	0	-	1	0	0	0
106	1	1	0	0	1	1	1	0	1	1	0	1	1	1	0	0	1	1	-	0	1	0	0	0	0
107	1	1	1	0	0	1	1	0	0	0	0	-	0	0	0	-	1	1	-	0	-	0	1	0	0
108	1	1	1	1	1	0	1	0	1	0	1	-	1	1	0	0	1	1	-	0	0	0	0	0	0
109	1	1	0	1	0	1	0	-	-	0	0	-	0	0	1	-	1	1	-	0	-	1	0	0	0
110	1	1	0	0	1	0	1	0	0	1	0	-	0	0	0	-	1	0	-	0	0	0	0	1	0
111	0	1	1	0	0	0	1	0	-	0	0	-	1	0	0	-	1	0	-	0	-	1	0	0	0
112	1	1	1	1	1	0	1	0	1	1	1	-	0	1	0	0	1	1	-	1	0	0	1	0	0
113	1	1	1	0	0	1	0	0	0	1	1	-	0	1	1	0	1	1	-	0	-	0	0	0	0

Diagnosis group	Sex	Age	Urgency	Severity	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	Source admission	Year
114	1	1	1	1	1	1	0	0	1	0	0	-	0	0	0	-	0	1	-	0	-	0	0	0	0
115	-	1	1	0	1	0	1	1	0	1	0	-	-	1	1	-	1	0	-	0	-	0	0	0	0
116	0	1	1	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	0	-	0
117	-	1	1	1	1	0	1	-	-	0	0	-	-	1	-	-	1	1	-	0	-	0	0	0	0
119	0	1	1	1	1	1	1	0	0	1	1	-	0	1	1	1	1	1	-	0	1	0	0	0	0
120	1	1	0	1	1	1	1	0	0	0	1	-	0	0	0	0	1	0	-	0	-	1	1	0	1
121	1	1	1	1	1	0	0	0	0	0	0	-	0	0	1	-	1	0	-	0	-	0	0	0	0
122	1	1	1	1	1	1	1	0	0	1	1	-	1	1	1	1	0	1	-	0	-	1	1	0	0
123	0	1	1	0	0	0	0	1	0	0	0	-	-	1	0	-	0	1	-	0	-	0	0	0	0
124	0	1	1	1	1	1	0	0	0	1	0	-	0	1	0	1	1	1	-	0	-	0	0	0	0
125	0	0	0	0	0	0	1	-	1	1	0	-	0	1	-	-	0	0	-	0	-	1	0	0	0
126	1	1	1	1	0	1	1	0	0	1	1	-	0	0	0	0	1	1	-	1	-	0	0	0	0
127	1	1	0	0	-	0	1	-	-	0	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
128	0	1	1	1	-	-	-	-	-	0	-	-	-	0	-	-	1	-	-	-	-	0	0	0	1
129	1	-	0	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	0
130	1	-	0	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
131	0	0	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	0
132	0	1	1	0	0	-	0	-	0	0	-	-	-	0	-	-	0	-	-	-	-	1	0	0	0
133	1	1	0	-	1	1	1	0	1	1	0	-	0	1	0	0	1	0	-	0	-	0	1	0	0
134	0	1	1	0	0	-	-	-	0	1	-	-	-	0	-	1	1	-	-	-	-	0	0	0	0
135	0	1	1	0	0	0	0	0	0	1	0	-	0	0	0	0	0	0	-	1	-	0	0	0	0
136	1	1	1	1	1	0	0	1	0	1	0	-	0	0	1	0	1	0	-	0	-	1	0	0	0
137	1	1	1	1	1	1	1	0	1	1	0	-	0	0	0	0	1	1	-	0	-	0	0	0	0
138	0	1	0	1	0	1	1	1	0	0	0	-	1	0	0	0	0	0	-	0	-	0	0	0	0
139	0	1	1	1	0	-	1	-	0	1	-	-	-	0	-	-	0	0	-	-	-	0	0	0	0
140	0	1	0	0	1	-	-	-	0	0	-	-	-	0	-	-	0	-	-	-	-	0	0	0	0
141	1	1	1	0	0	-	1	-	-	0	-	-	-	0	-	-	0	-	-	-	-	0	0	-	0
142	1	1	1	1	0	1	1	0	0	1	0	-	1	1	1	0	1	1	-	0	0	0	0	1	0
143	1	1	1	1	1	1	1	0	0	1	0	-	1	1	1	0	1	1	-	0	0	0	0	0	0
144	1	1	0	1	1	1	1	0	1	0	0	-	1	0	0	0	1	0	-	0	-	0	0	0	0
145	0	0	0	0	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	0	0	0	0
146	1	1	0	1	0	0	0	0	0	1	-	-	1	0	0	-	1	1	-	0	-	0	0	1	0
147	1	1	0	1	0	0	1	0	0	1	-	-	-	0	-	-	0	1	-	0	-	0	0	0	0
148	1	1	0	-	1	1	1	0	0	1	0	-	1	1	1	0	1	1	-	0	-	0	0	0	0
149	0	1	1	1	1	0	1	0	1	0	0	-	0	0	0	0	1	1	-	0	-	0	0	0	0
150	1	1	1	1	0	0	0	-	-	0	-	-	-	0	1	-	0	0	-	-	-	0	0	0	0
151	0	0	-	-	0	0	-	-	-	-	-	-	-	0	-	-	0	-	-	-	-	0	0	0	0
152	0	1	0	-	1	0	1	0	0	0	0	-	0	0	1	-	0	1	-	0	-	0	0	0	0
153	1	1	1	-	1	1	1	0	0	0	0	-	1	0	0	0	1	0	-	0	0	0	0	0	0
154	1	1	1	-	1	1	0	0	1	0	0	-	1	1	0	-	1	1	-	0	-	0	0	0	0
155	0	1	1	1	1	-	0	-	-	0	-	-	-	0	-	-	1	0	-	0	-	0	1	0	1
156	1	1	1	0	1	1	1	0	0	1	1	-	0	1	1	1	1	1	-	1	0	0	1	1	0
157	1	1	1	1	0	1	1	0	1	1	0	-	0	1	0	0	1	0	-	0	-	0	0	1	0

Diagnosis group	Sex	Age	Urgency	Severity	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	Source admission	Year
	64	103	77	68	59	55	62	16	25	57	29	1	31	48	36	9	71	55	0	18	5	18	19	28	11

The numbers of the comorbidity groups in the header of the table above 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 II: Results of the logistic regressions (inter-hospital model)

Statistical significance (95% confidence) of the covariates for the 122 logistic regressions (1=significant; 0=non-significant; "-"=variable dropped because all categories are collapsed, due to < 50 admissions or no readmissions in all but one category).

Diagnosis group	Sex	Age	Urgency	Severity	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	Source admission	Year
1	0	1	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
2	0	1	0	0	0	0	1	1	0	0	0	-	0	1	0	0	1	1	-	0	-	0	0	0	0
3	0	1	0	0	0	0	0	1	0	0	0	-	1	0	0	-	1	0	-	0	-	0	0	0	0
4	0	0	0	1	-	-	-	-	-	0	-	-	-	0	-	-	0	1	-	0	-	0	0	-	0
5	0	0	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	0	0	0	1
6	0	1	1	1	0	1	0	1	0	0	0	-	1	0	1	-	0	1	-	0	0	0	1	0	0
37	1	1	1	1	0	1	1	0	0	1	1	-	0	1	0	0	1	0	-	0	-	0	0	0	0
38	1	1	1	0	1	1	1	0	0	0	0	-	0	0	0	-	1	1	-	0	-	0	0	0	0
39	0	1	1	1	0	1	0	0	0	1	0	-	0	0	1	-	1	0	-	0	-	0	0	0	0
40	1	1	0	1	1	1	1	0	0	0	0	-	0	1	1	-	1	0	-	0	-	0	0	0	0
41	1	1	1	1	0	1	0	1	1	0	0	-	0	1	0	1	1	0	-	0	-	0	0	0	0
42	1	1	1	1	0	0	0	0	1	1	0	-	1	0	0	0	1	1	-	1	0	0	0	0	0
43	0	1	0	0	-	-	-	-	-	0	-	-	0	0	-	-	-	-	-	-	-	0	0	-	0
44	0	1	1	1	0	0	0	0	1	0	0	-	0	0	-	-	0	1	-	0	-	1	0	0	0
45	1	1	1	1	1	1	0	0	1	1	1	0	1	0	1	0	1	0	-	0	1	0	0	0	0
46	0	1	0	-	0	-	0	-	-	0	-	-	-	0	-	-	0	0	-	1	-	1	0	0	0
51	0	1	1	1	0	-	-	0	-	0	-	-	-	0	-	0	0	0	-	-	-	0	0	1	0
52	1	0	0	0	1	-	-	-	0	0	-	-	-	0	-	-	0	-	-	-	-	0	0	0	0
53	1	1	1	1	0	-	0	0	0	1	-	-	-	0	-	0	0	1	-	-	-	0	0	0	0
54	0	0	0	0	0	-	0	1	-	0	-	-	-	0	-	0	0	0	-	0	-	0	0	0	0
55	0	1	1	1	0	0	1	0	0	1	0	-	0	0	0	0	0	0	-	0	-	0	0	0	0
56	1	1	0	1	0	-	0	0	0	0	-	-	0	1	-	-	1	0	-	0	-	0	0	0	0
57	1	1	1	1	1	1	1	1	0	1	0	-	0	1	0	0	1	1	-	1	-	0	0	1	1
58	1	1	1	1	1	1	1	1	0	1	1	-	1	1	1	0	1	0	-	0	-	1	0	0	0
59	0	1	1	0	0	1	1	0	0	1	0	-	0	0	0	-	1	0	-	1	-	0	0	1	1
60	0	1	1	1	1	1	0	0	-	0	1	-	0	0	0	-	1	0	-	1	-	0	0	1	0
61	0	0	0	1	1	1	1	0	-	0	1	-	0	0	1	-	1	0	-	-	-	0	0	0	1
62	1	1	1	1	1	1	1	1	0	1	1	-	0	1	1	0	1	1	-	0	-	1	0	1	1
63	0	1	1	0	0	1	1	1	0	1	1	-	1	1	1	0	1	0	-	0	-	0	0	1	0
64	1	1	0	-	1	1	1	0	0	1	0	-	1	1	1	0	1	1	-	1	-	0	0	1	0
65	0	1	1	1	1	1	0	0	0	1	1	-	0	0	0	0	1	1	-	1	-	0	1	1	0
66	0	0	0	0	0	0	0	-	-	0	-	-	-	0	-	-	0	-	-	-	-	0	0	1	1
67	0	1	1	0	1	1	1	0	0	0	0	-	-	0	1	-	1	0	-	-	-	0	0	1	0
68	1	1	1	1	1	1	1	0	0	1	1	-	0	1	1	0	1	1	-	0	-	0	0	0	0
69	1	0	0	1	0	1	0	0	-	1	-	-	-	0	-	-	1	0	-	-	-	0	0	0	0

Diagnosis group	Sex	Age	Urgency	Severity	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	Source admission	Year
70	1	1	1	0	1	1	1	0	1	1	0	-	0	1	1	0	1	0	-	1	0	1	0	0	1
71	1	1	1	1	1	1	1	1	1	1	1	-	1	1	1	0	1	1	-	0	-	0	0	1	0
72	1	1	0	1	1	1	1	1	0	0	0	-	1	0	1	0	1	0	-	1	-	0	0	0	0
73	1	1	1	1	1	1	1	0	0	1	1	-	0	1	1	0	1	0	-	0	-	0	1	0	0
74	0	0	1	1	1	0	0	0	0	0	0	-	0	0	0	0	0	0	-	0	-	0	0	1	0
75	1	1	1	1	1	1	1	0	0	0	1	-	-	0	1	-	1	0	-	0	-	0	0	0	0
76	0	1	1	1	1	1	1	0	1	1	0	-	0	1	1	0	1	0	-	0	-	0	0	1	0
77	0	1	1	1	0	0	1	0	0	1	0	-	1	1	0	-	0	1	-	0	0	0	0	1	0
78	1	1	1	1	1	1	1	0	1	1	1	-	0	1	1	1	1	1	0	0	0	0	0	1	0
79	1	1	0	0	1	1	1	0	0	1	1	-	0	0	-	-	1	1	-	0	-	0	0	0	0
80	1	1	1	1	1	1	1	1	0	1	0	-	0	0	1	0	0	1	-	0	-	0	0	0	0
81	1	0	0	0	0	0	0	-	0	1	0	-	-	0	-	-	0	1	-	0	-	0	0	0	0
82	1	1	1	1	1	1	1	0	1	0	0	-	0	1	1	1	1	1	-	1	-	1	1	0	0
83	1	1	0	-	1	1	0	-	-	1	1	-	-	1	0	-	0	1	-	-	-	0	0	0	0
84	1	1	0	-	1	1	0	0	0	0	-	-	0	0	-	0	0	1	-	1	-	0	0	0	0
85	0	1	1	1	0	1	0	0	0	0	0	-	1	0	0	-	0	0	-	0	-	0	0	1	0
86	0	0	0	1	0	0	0	0	-	1	-	-	0	1	-	-	0	0	-	0	-	0	0	0	0
87	0	0	0	0	0	-	-	-	-	0	-	-	-	0	-	-	-	0	-	0	-	0	0	-	0
88	0	1	0	1	1	1	0	0	1	1	1	-	0	1	0	1	1	1	-	0	-	0	1	0	0
89	0	1	1	1	1	1	0	0	1	1	0	-	1	1	1	0	1	1	-	0	-	1	0	0	0
90	0	1	1	1	1	1	1	0	0	1	1	-	1	1	0	1	1	1	-	0	0	0	1	0	0
91	0	1	1	1	0	-	-	-	-	1	-	-	-	0	-	-	0	1	-	0	-	1	0	1	0
92	0	1	1	1	0	0	1	1	0	0	0	0	1	0	0	-	1	1	-	0	0	0	0	0	0
93	0	0	0	0	0	-	1	-	-	0	-	-	-	0	-	-	0	1	-	-	-	0	0	-	0
94	0	0	0	1	0	0	1	-	-	0	0	0	1	0	0	-	0	1	-	0	1	1	0	0	0
95	0	1	1	-	0	-	0	-	-	1	0	-	0	1	-	-	0	0	-	-	-	0	1	0	0
96	0	0	0	0	0	-	0	-	-	0	-	-	1	0	-	-	1	0	-	0	0	0	0	0	0
97	1	1	1	1	1	0	1	0	0	1	0	-	1	1	1	-	1	0	-	0	-	0	0	0	0
98	0	0	1	-	0	-	0	-	-	0	-	-	0	0	-	-	0	0	-	-	-	0	0	0	0
99	0	1	0	1	0	1	0	0	1	0	0	-	0	0	0	0	0	0	-	0	-	0	0	0	0
100	0	1	1	1	1	0	0	0	0	1	0	-	0	1	0	-	1	0	-	0	-	0	0	0	0
101	0	1	1	1	0	-	0	-	0	0	1	-	-	0	-	-	0	1	-	0	-	0	0	0	0
102	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	1	1	0	-	1	1	0	0	1	0
103	0	1	1	1	0	-	0	-	-	0	-	-	0	1	-	-	0	0	-	-	0	0	0	0	0
104	1	1	1	1	1	1	1	0	0	1	0	-	1	1	0	-	1	0	-	1	1	0	0	0	0
105	1	1	0	1	0	0	0	0	0	0	0	-	0	0	0	-	1	0	-	0	-	1	0	0	0
106	1	1	0	0	1	0	1	0	1	1	0	1	1	1	0	0	1	1	-	0	1	0	0	0	0
107	1	1	0	0	0	1	1	0	0	0	0	-	0	0	0	-	1	1	-	0	-	1	1	0	0
108	1	1	1	1	1	0	1	0	1	0	1	-	1	0	0	0	1	1	-	0	0	0	0	0	0
109	1	1	0	1	0	1	0	-	-	0	0	-	0	0	1	-	1	1	-	0	-	1	0	0	0
110	1	1	0	0	0	0	1	0	0	1	0	-	0	0	0	-	1	0	-	0	0	0	0	0	0
111	0	1	1	0	0	0	0	0	-	0	0	-	1	0	0	-	1	0	-	0	-	1	0	0	0
112	1	1	1	1	1	1	1	0	1	1	1	-	0	1	0	0	1	1	-	1	0	0	0	0	0
113	1	1	1	0	0	1	0	0	0	1	1	-	0	1	1	0	1	1	-	0	-	0	0	0	0

Diagnosis group	Sex	Age	Urgency	Severity	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	Source admission	Year
114	1	1	1	1	1	1	0	0	1	0	0	-	0	0	0	-	0	1	-	0	-	0	0	0	0
115	-	1	1	1	1	1	1	1	0	1	0	-	-	1	1	-	1	0	-	0	-	0	0	0	0
116	0	1	1	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	1	0	-	0
117	-	1	1	1	1	0	1	-	-	0	0	-	-	1	-	-	1	0	-	0	-	0	0	0	0
119	0	1	0	1	1	1	1	0	0	1	1	-	0	1	1	1	1	1	-	0	1	0	0	0	0
120	1	1	0	1	1	1	1	0	0	0	1	-	0	0	0	0	1	0	-	0	-	1	1	0	1
121	1	1	1	1	1	0	0	0	0	0	0	-	0	0	1	-	1	0	-	0	-	0	0	0	0
122	1	1	1	1	1	0	1	1	0	1	1	-	1	1	1	1	0	1	-	0	-	1	1	0	0
123	0	1	1	0	1	0	0	1	0	0	0	-	-	1	0	-	0	1	-	0	-	0	0	0	0
124	0	1	1	0	1	0	0	0	0	1	0	-	0	1	0	1	1	1	-	0	-	0	0	0	0
125	0	0	0	0	0	0	1	-	0	1	0	-	0	1	-	-	0	0	-	0	-	0	0	0	0
126	0	1	1	1	0	1	1	0	0	1	1	-	0	1	0	0	1	1	-	0	-	0	0	0	0
127	1	1	0	1	-	0	1	-	-	0	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
128	0	1	1	1	-	-	-	-	-	0	-	-	-	0	-	-	1	-	-	-	-	0	0	0	1
129	1	-	0	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	0
130	1	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
131	1	0	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	1	0
132	0	1	1	0	0	-	0	-	0	0	-	-	-	0	-	-	0	-	-	-	-	1	0	0	0
133	1	1	0	-	1	1	1	0	1	1	0	-	0	1	0	0	1	0	-	0	-	0	0	0	0
134	0	1	1	0	0	-	-	-	0	1	-	-	-	0	-	1	1	-	-	-	-	0	0	0	0
135	0	1	1	0	1	0	0	0	0	1	0	-	0	0	0	0	0	0	-	0	-	0	0	0	0
136	1	1	1	1	1	0	0	1	0	1	0	-	0	0	1	0	0	0	-	0	-	1	0	0	0
137	1	1	1	0	1	1	1	0	1	1	0	-	0	0	0	1	1	1	-	0	-	0	0	0	0
138	0	1	1	1	0	1	1	0	0	0	0	-	1	0	0	0	0	0	-	0	-	0	0	1	0
139	0	1	1	1	1	-	1	-	0	1	-	-	-	0	-	-	1	0	-	-	-	0	0	0	0
140	0	1	0	0	1	-	-	-	0	0	-	-	-	0	-	-	0	-	-	-	-	0	0	0	0
141	1	1	1	0	0	-	1	-	-	0	-	-	-	0	-	-	0	-	-	-	-	0	0	-	0
142	1	1	1	1	1	1	1	0	0	1	0	-	1	1	1	0	1	1	-	0	0	0	0	0	0
143	1	1	1	1	1	1	1	0	0	1	0	-	1	1	1	0	1	1	-	0	0	0	0	0	0
144	1	1	0	1	1	1	1	0	1	0	0	-	1	0	0	0	1	0	-	0	-	0	0	0	0
145	0	0	0	0	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	0	0	0	0
146	1	1	0	1	1	0	0	0	0	1	-	-	1	0	0	-	1	1	-	0	-	0	0	1	0
147	1	1	0	1	0	0	1	0	0	1	-	-	-	0	-	-	0	1	-	0	-	0	0	0	0
148	1	1	0	-	1	1	1	0	0	1	0	-	1	1	1	0	1	1	-	0	-	0	0	0	0
149	0	1	1	0	1	0	1	0	1	0	0	-	0	0	0	0	1	1	-	0	-	0	0	0	0
150	1	1	1	1	0	0	0	-	-	0	-	-	-	0	0	-	0	0	-	-	-	0	0	0	0
151	0	0	-	-	0	0	-	-	-	-	-	-	-	0	-	-	0	-	-	-	-	0	0	0	1
152	0	1	0	-	1	1	1	0	0	0	0	-	0	0	1	-	0	1	-	0	-	0	0	0	0
153	1	1	1	-	1	1	1	0	1	0	0	-	1	1	0	0	1	0	-	0	0	0	0	1	0
154	1	1	1	-	0	1	0	0	0	0	0	-	0	1	0	-	1	1	-	0	-	0	0	0	0
155	0	1	1	0	1	-	0	-	-	0	-	-	-	0	-	-	1	1	-	0	-	0	1	0	1
156	1	1	1	0	1	1	1	0	0	1	1	-	1	1	1	1	1	1	-	1	0	0	0	1	0
157	1	1	1	1	0	1	1	0	1	1	0	-	0	1	0	0	1	0	-	0	-	1	0	0	0

Diagnosis group	Sex	Age	Urgency	Severity	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	Source admission	Year
	61	101	76	73	61	59	60	18	23	57	27	1	31	48	34	12	72	52	0	15	6	19	13	24	11

The numbers of the comorbidity groups in the header of the table above 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 III: AUC

The area under the curve (AUC) or C-Statistic for the logistic regressions of the 122 main diagnosis groups.

			Intra-hospital model		Inter-hospital model	
Diagnosis group[*)]		**Number of index admissions**	**Number of readmissions**	**AUC**	**Number of readmissions**	**AUC**
1	Tuberculosis	676	78	0.68	100	0.70
2	Septicemia (except in labor)	6 657	996	0.60	1 067	0.60
3	Bacterial infection; unspecified site	2 739	422	0.63	441	0.64
4	Mycoses	842	162	0.65	175	0.65
5	HIV infection	459	81	0.72	88	0.70
6	Hepatitis, viral and other infections	10 787	902	0.62	1 032	0.62
37	Other and unspecified benign neoplasm	30 390	1 805	0.65	2 070	0.66
38	Thyroid and other endocrine disorders	9 784	827	0.69	911	0.68
39	Diabetes mellitus without complication	6 977	521	0.67	576	0.66
40	Diabetes mellitus with complications	9 408	1 598	0.67	1 697	0.66
41	Nutritional deficiencies and other nutritional, endocrine, and metabolic disorders	22 720	2 016	0,67	2 241	0.68
42	Fluid and electrolyte disorders	12 927	1 707	0.65	1 851	0.65
43	Cystic fibrosis	1 004	152	0.64	174	0.65
44	Immunity and coagulation disorders, hemorrhagic disorders	4 829	841	0.62	916	0.62
45	Deficiency and other anemia	18 188	2 830	0.62	3 020	0.62
46	Diseases of white blood cells	3 176	529	0.60	522	0.62
51	Meningitis, encephalitis, and other central nervous system infections	3 793	340	0.65	383	0.64
52	Parkinson`s disease	2 769	252	0.59	287	0.59
53	Multiple sclerosis and other degenerative nervous system conditions	5 967	562	0.62	644	0.62
54	Paralysis and late effects of cerebrovascular disease	1 879	147	0.66	172	0.65
55	Epilepsy and convulsions	18 082	1 524	0.59	1 784	0.58
56	Coma, stupor, and brain damage	1 220	129	0.69	152	0.69
57	Headache and other disorders of the sense organs	33 378	1 456	0.63	1 707	0.63
58	Other nervous system disorders	46 495	2 293	0.66	2 676	0.67
59	Heart valve disorders	15 672	1 552	0.61	1 995	0.60
60	Peri-, endo-, myocarditis, and cardiomyopathy	8 097	885	0.64	998	0.63
61	Essential hypertension, hypertension with compl., and secondary hypertension	5 401	450	0.66	492	0.64
62	Acute myocardial infarction	51 060	4 311	0.63	4 685	0.64
63	Coronary atherosclerosis and other heart disease	61 253	5 132	0.61	6 223	0.61
64	Nonspecific chest pain	39 376	2 502	0.64	2 911	0.63
65	Pulmonary heart disease	13 587	1 038	0.68	1 155	0.69
66	Other and ill-defined heart disease	1 381	136	0.67	160	0.66
67	Conduction disorders (heart disease)	9 272	728	0.64	803	0.63
68	Cardiac dysrhythmias	56 964	5 369	0.64	6 264	0.61
69	Cardiac arrest and ventricular fibrillation	3 268	191	0.67	221	0.66
70	Congestive heart failure, nonhypertensive	41 809	6 518	0.59	7 141	0.59

Diagnosis group[*)]		Number of index admissions	Intra-hospital model		Inter-hospital model	
			Number of readmissions	AUC	Number of readmissions	AUC
71	Acute cerebrovascular disease	50 645	3 438	0.62	4 034	0.61
72	Transient cerebral ischemia, and other cerebrovascular disease	20 177	1 697	0.64	1 974	0.64
73	Peripheral and visceral atherosclerosis	14 230	2 542	0.63	2 713	0.63
74	Aortic and other artery aneurysms	10 699	1 302	0.58	1 458	0.57
75	Aortic and arterial embolism or thrombosis	6 763	1 141	0.62	1 229	0.62
76	Other circulatory disease	14 309	2 028	0.61	2 177	0.60
77	Phlebitis, varicose veins, and hemorrhoids	6 188	632	0.66	701	0.67
78	Pneumonia	50 607	5 589	0.63	5 967	0.62
79	Influenza	3 606	313	0.69	345	0.69
80	Tonsillitis and upper respiratory infections	36 254	2 131	0.66	2 364	0.66
81	Acute bronchitis	7 897	690	0.60	775	0.59
82	Chronic obstructive pulmonary disease and bronchiectasis	51 174	9 376	0.56	9 925	0.56
83	Asthma	12 782	1 215	0.61	1 331	0.61
84	Aspiration pneumonitis; food/vomitus	2 326	371	0.63	411	0.63
85	Pleurisy; pneumothorax; pulmonary collapse	10 177	1 480	0.61	1 619	0.60
86	Respiratory failure; insufficiency; arrest	2 282	328	0.64	368	0.64
87	Lung disease due to external agents	700	119	0.60	129	0.60
88	Other lower respiratory disease	10 691	1 327	0.61	1 494	0.60
89	Other upper respiratory disease	33 045	2 443	0.72	2 741	0.72
90	Intestinal infection	19 217	1 896	0.65	2 045	0.64
91	Disorders of mouth, teeth, and jaw	8 654	259	0.73	299	0.71
92	Esophageal disorders	6 267	719	0.63	795	0.63
93	Gastroduodenal ulcer	1 878	178	0.65	193	0.65
94	Gastritis, duodenitis, and other disorders of stomach and duodenum	3 498	475	0.66	524	0.65
95	Appendicitis and other appendiceal conditions	26 387	1 867	0.57	1 941	0.57
96	Peritonitis and intestinal abscess	1 820	354	0.65	380	0.64
97	Abdominal hernia	20 986	1 736	0.64	1 911	0.64
98	Regional enteritis and ulcerative colitis	7 886	1 153	0.57	1 240	0.56
99	Intestinal obstruction without hernia	12 920	1 904	0.57	2 030	0.57
100	Diverticulosis and diverticulitis	16 218	1 665	0.62	1 740	0.62
101	Anal and rectal conditions	9 807	900	0.61	950	0.61
102	Biliary tract disease	58 437	7 725	0.64	8 223	0.65
103	Liver disease; alcohol-related	2 493	637	0.63	702	0.63
104	Other liver diseases	7 243	1 830	0.66	1 998	0.67
105	Pancreatic disorders (not diabetes)	12 575	2 440	0.57	2 612	0.57
106	Gastrointestinal hemorrhage	14 624	2 053	0.61	2 225	0.61
107	Noninfectious gastroenteritis	8 535	981	0.63	1 057	0.62
108	Other gastrointestinal disorders	18 375	2 384	0.60	2 617	0.59
109	Nephritis; nephrosis; renal sclerosis	6 171	692	0.66	768	0.65
110	Acute and unspecified renal failure	6 760	1 189	0.60	1 283	0.59
111	Chronic kidney disease	6 295	1 243	0.58	1 318	0.59
112	Urinary tract infections	36 581	4 569	0.60	4 889	0.60
113	Calculus and other diseases of urinary tract	35 155	5 151	0.62	5 436	0.62

Diagnosis group[*)]		Number of index admissions	Intra-hospital model		Inter-hospital model	
			Number of readmissions	AUC	Number of readmissions	AUC
114	Genitourinary symptoms and ill-defined conditions	12 353	1 554	0.67	1 624	0.67
115	Hyperplasia of prostate and other male genital disorders	18 354	1 634	0.61	1 705	0.61
116	Nonmalignant breast conditions	7 173	212	0.71	230	0.70
117	Prolapse and other female genital disorders	29 276	1 386	0.68	1 493	0.69
119	Skin and subcutaneous tissue infections	22 594	1 890	0.67	2 025	0.67
120	Other skin disorders, chronic ulcer of skin	9 514	1 167	0.68	1 275	0.68
121	Infective arthritis and osteomyelitis	5 677	718	0.61	753	0.61
122	Osteoarthritis, rheumatoid arthritis, and other musculoskeletal deformities	101 632	4 714	0.65	4 991	0.65
123	Other non-traumatic joint disorders	7 390	405	0.74	461	0.74
124	Spondylosis, back problems, and osteoporosis	39 329	2 136	0.66	2 560	0.66
125	Pathological fracture	2 827	316	0.65	345	0.64
126	Other connective tissue disease	21 953	893	0.71	978	0.71
127	Cardiac and circulatory congenital anomalies	3 828	357	0.62	498	0.61
128	Noncardiac congenital anomalies	12 551	913	0.65	1 100	0.66
129	Short gestation; low birth weight; and fetal growth retardation	24 199	1 878	0.65	2 062	0.65
130	Intrauterine hypoxia, perinatal asphyxia, and jaundice	20 952	890	0.55	1 021	0.55
131	Other perinatal conditions	81 234	3 685	0.54	4 245	0.54
132	Joint disorders and dislocations; trauma-related; sprains and strains	15 338	412	0.74	464	0.74
133	Fracture of neck of femur (hip)	30 493	2 088	0.61	2 240	0.61
134	Skull and face fractures, spinal cord injury	4 943	213	0.68	267	0.68
135	Fracture of upper limb	20 908	1 137	0.74	1 278	0.74
136	Fracture of lower limb	22 288	1 912	0.68	2 073	0.69
137	Other fractures	19 532	1 113	0.62	1 305	0.61
138	Intracranial injury	18 573	758	0.72	970	0.71
139	Crushing injury or internal injury	9 289	463	0.67	532	0.67
140	Open wounds of head; neck; and trunk	2 727	124	0.70	151	0.68
141	Open wounds of extremities	2 512	179	0.70	194	0.69
142	Complication of device, implant or graft	38 620	5 619	0.64	6 072	0.64
143	Complications of surgical procedures or medical care	40 684	5 540	0.59	5 950	0.59
144	Superficial injury; contusion	20 055	913	0.73	1 035	0.72
145	Burns	1 659	70	0.71	94	0.68
146	Poisoning by psychotropic agents, drugs, or other medications	13 197	987	0.64	1 195	0.64
147	Other injuries and conditions due to external causes	4 629	365	0.67	413	0.66
148	Syncope	20 726	1 351	0.64	1 553	0.62
149	Fever of unknown origin	11 292	1 608	0.63	1 695	0.62
150	Lymphadenitis and gangrene	2 968	415	0.70	438	0.70
151	Shock	444	59	0.68	66	0.66
152	Nausea and vomiting	6 294	942	0.61	999	0.61
153	Abdominal pain	23 617	2 553	0.58	2 825	0.58
154	Malaise and fatigue	5 767	634	0.67	693	0.66
155	Allergic reactions	4 542	361	0.70	397	0.69

Diagnosis group[*)]		Number of index admissions	Intra-hospital model		Inter-hospital model	
			Number of readmissions	AUC	Number of readmissions	AUC
156	Rehabilitation and other aftercare, medical examination/evaluation/screening	56 868	3 941	0.61	4 659	0.61
157	Residual codes; unclassified	28 830	1 746	0.71	1 996	0.70

[*)] The diagnosis group numbers refer to the file 'Classification of variables' published together with the HSMR 2016 methodological report (see Van der Laan *et al*. 2017b). In this file, the CCS-groups and corresponding ICD10-codes of the 157 diagnosis groups used for the HSMR are given. For the readmission ratio only 122 of these groups are used, but the numbering was kept the same.

Explanation of symbols

Empty cell	Figure not applicable
.	Figure is unknown, insufficiently reliable or confidential
*	Provisional figure
**	Revised provisional figure
2017–2018	2017 to 2018 inclusive
2017/2018	Average for 2017 to 2018 inclusive
2017/'18	Crop year, financial year, school year, etc., beginning in 2017 and ending in 2018
2015/'16–2017/'18	Crop year, financial year, etc., 2015/'16 to 2017/'18 inclusive

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

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