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Community Acquired Pneumonia (CAP) hospitalizations and deaths: is there a role for quality improvement through inter-hospital comparisons?

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Abstract

Objective: To assess between-hospital variations in standardized in-hospital mortality ratios of community acquired pneumonia, and identify possible leads for quality improvement.

Design: We carried out a retrospective analysis of Belgian hospital discharge records by means of a sensitivity analysis, consisting of hierarchical logistic regression models, and intended to yield leads to improvement whilst disentangling therapeutic attitudes and biases. To facilitate the detection of false negative/ positive results, we added an inconclusive zone to the funnel plots. Data quality was validated by comparison with (1) the results of an on-site audit, (2) alternative data from the largest Belgian Sickness Fund, and (3) published German hospital data.

Setting: All Belgian hospital discharge records in the years 2004-2007.

Study participants: 111,776 adult patients admitted for community acquired pneumonia.

Main outcome measure: Risk-adjusted standardized in-hospital mortality ratios.

Results: Out of the 111 hospitals, the sensitivity analysis identified five and six outlying hospitals, with standardized mortality ratios of community acquired pneumonia consistently on the extremes of their distribution, as providing possibly better or worse care, respectively, and 18 other hospitals as having possible quality weaknesses/strengths. At the individuals' level of the analysis, adjusted odds ratios showed the paramount importance of old age, co-morbidity and mechanical ventilation. The data compared well with the different validation sources.

Conclusions: Despite the limitations inherent to administrative data, it seemed possible, by carrying out a sensitivity analysis, to establish inter-hospital differences in standardized in—

hospital mortality ratios of community acquired pneumonia and to identify leads for quality improvement. Monitoring is needed to assess progress in quality.

Keywords: Benchmarking; Statistical Methods; Standardized Mortality Ratio; Funnel Plot; Health services research.

INTRODUCTION

Inter-hospital comparisons of Community-Acquired Pneumonia (CAP) standardized in-hospital mortality ratios (CAP-SMRs) may lead to an improved understanding of contextual influences on CAP, one of the leading causes of hospital admission, social and economic costs, and death throughout the world [1]. However this type of comparison requires sufficiently reliable data, which can be challenging if these data serve multiple purposes (e.g., both reimbursement and quality assurance). Inadequate risk-adjustment and creep pose threats to data reliability such that widely used proprietary risk-adjustment may yield erroneous conclusions [2]. Unfortunately, recommended severity scores [3,4], laboratory data and physiologic information [5] are often not recorded in administrative databases, such as the ones we used here. Despite these imperfections, comparative information derived from administrative data is frequently put forward as a basis for quality improvement [6].

In an effort to encourage the hospital system to assume responsibility, the Belgian Ministry of Public Health decided to foster initiatives of quality improvement. Hereto a limited set of indicators was selected from the AHRQ Inpatient Quality Indicators, including the CAP-SMR[7]. We aimed, by establishing the existence of inter-hospital differences in CAP-SMR, (1) to evaluate to which extent Belgian discharge records allow the assessment of quality of care in the field of CAP, and (2) to identify starting points for improvement.

METHODS

Data sources

Belgian hospitals are required to register discharge data, stored in the so-called Minimal Clinical Data (MCD) database. It includes an unbounded number of ICD-9-CM coded diagnoses and procedures for each admission, which allows computing the Carlson's co-morbidity index (CCI) (see Appendix 1: Carlson's Comorbidity Index, D'Hoore implementation) [8]. However, results of laboratory investigations, technical examinations such as X-rays, or patients' socio-economic status (SES) are not included. Moreover, the ICD-9-CM classification provides only limited information about severity of illness. The notion of "intensity of care", based on the registration of invasive mechanical ventilation (IMV), non-invasive mechanical ventilation (NMV) and, otherwise, basic care (see Appendix 2: ICD-9 codes), allowed us to a certain extent to fill this gap [3,9] .

A complementary Belgian data source, the Carenet hospitalization database (see Appendix 3: The Carenet hospitalization database), operating independently from the MCD database, was used to investigate the validity of the MCD data. Apart from a patient's age, gender and survival, it provides hospitalization data including primary and secondary diagnoses, patient and hospital identifiers and time and date of hospitalization. Carenet enabled us to compare between both registries the in-hospital 30-day-mortality rates of hospitalized CAP globally and by age classes.

In addition, we checked the MCD's age distribution, age- specific incidence and mortality proportions of CAP hospital admissions against tables and figures of published German hospital data [3], which were collected according to a predefined quality report sheet as part of a nationwide mandatory performance measurement program.

Finally, we compared the MCD data with the results of audits, carried out by public service physicians, who compared the registered diagnostic codes with the original medical files, applying reference coding rules.

Definition of the study population

In the MCD database, all admissions (N= 146,857) having CAP [7] as principal diagnosis in the years 2004-2007 (see Appendix1: ICD-9-CM codes) were selected. Records without information regarding vital status at discharge (N=77), or concerning ages less than 18 years (N=37,044), or pregnant women (N=127) or transfers to another hospital (N=2102) were excluded. Thus we retained 107,507 CAP patients. Striving for completeness rather than strictly applying the coding principles, we also included records with acute respiratory failure (ARF) as principal and CAP as secondary diagnosis (N= 4269), ending up with a potential study population of 111,776 observations, across 128 hospitals.

In the absence of personal identifiers, incidences were estimated excluding stays of patients transferred to another hospital (N= 769).

Concentrating on an inter-hospital comparison and in order to obtain statistical stability, we further excluded 17 hospitals registering fewer than 80 observations during the period 2004-7 (N=141 stays) or fatalities in patients with a LOS < 3 days (N=2665). The latter are highly dependent on the clinical status of the patient at presentation whereas late mortality seems to be associated more closely with clinical management factors [10]. This way we obtained an *inter-hospital* study population of 108,213 cases admitted to 111 hospitals.

Statistical methods

Since data of neither out-of-hospital cases nor out-of-hospital fatalities were available, our outcome of interest was the CAP in-hospital standardized mortality ratio (SMR). This standardized mortality ratio, defined as one hundred times the ratio of the *observed* deaths (O) to the *expected* deaths (E), was constructed to identify both high- and low-performance quality outliers [11]. The expected deaths are the counterfactual, unobservable mortality experience, estimated from a hierarchical model, commonly applied in the field of hospital performance [11-13].

Hospitals with an SMR < 100 and a confidence interval not including 100, are considered high-performance outliers. Conversely, hospitals with an SMR > 100 and a confidence interval not including 100 are considered low-performance outliers. We constructed a hierarchical model, in this case a mixed effects multiple logistic regression model, with hospitals as random intercepts, accounting for within hospital correlations [14]:

$$Y_{ij} \sim Bernoulli(p_{ij}),$$

$$logit(p_{ij}) = \boldsymbol{X}_{ij}^{\boldsymbol{T}}\boldsymbol{\beta} + b_i,$$

$$b_i \sim N(0, \sigma^2),$$

with p_{ij} the probability that patient j within hospital i dies, $\boldsymbol{\beta}$ the vector of regression coefficients for $\boldsymbol{X}_{ij}$, the matrix of risk adjustment variables for the j^{th} patient at the i^{th} hospital. The model intercept is given by α is and b_i is the hospital-specific random intercepts usually taken to be normally distributed with mean zero and standard deviation to be estimated.

For each hospital i we calculated both the observed (O_i) and expected (E_i) number of fatalities:

$$O_i = \sum_{j=1}^{n_i} Y_{ij} \text{ and } E_i = \sum_{j=1}^{n_i} \hat{p}_{ij},$$

with $\hat{p}_{ij} = logit^{-1}(\boldsymbol{X}_{ij}^{\boldsymbol{T}}\widehat{\boldsymbol{\beta}})$, the estimate of $logit^{-1}(\boldsymbol{X}_{ij}^{\boldsymbol{T}}\boldsymbol{\beta}) = E(Y_{ij}|\boldsymbol{X}_{ij}, b_i = 0)$, $\widehat{\boldsymbol{\beta}}$ is the vector of fitted regression coefficients and n_i the number of CAP hospitalizations in hospital i. Since the random intercept component of the hierarchical model accounts for between-hospital variability, only the fixed-effects coefficients $\widehat{\boldsymbol{\beta}}$ were used to calculate the expected deaths, thus removing the impact of individual hospital quality on the expected mortality. In other words the probability of death for a patient treated at an "average quality" hospital (with random intercept $b_i = 0$) [14] is estimated.

From the observed and expected number of fatalities, we calculated the standardized mortality ratio (SMR_i) for hospital i as $SMR_i = O_i/E_i * 100$, that should be interpreted as a percentage deviation from the hypothetical average hospital. As we are modeling the ratio of the number of fatalities over the number of cases and since the criteria for approaching this binomial distribution by a Poisson distribution [15] were not met, a hierarchical logistic regression was chosen. The SMRs are graphically represented using funnel plots with control limits based on the 99.8- and 95-percentiles of the exact binomial distribution as described in Spiegelhalter [16].

In our mixed-effects multiple logistic regression model, a generalized linear mixed model (GLMM), parameter estimation was carried out using an integral approximation method (the Gauss-Hermite quadrature with specification of 50 quadrature points), that numerically evaluates the marginal log-likelihood of the model. The advantage of this method is that it manipulates the likelihood and all of its derived quantities with high precision. By choosing the number of quadrature points sufficiently highly, arbitrary precision can be reached. As a consequence, trustworthy point estimates, standard errors, confidence intervals, and likelihood

ratio test statistics result. Thus, we were able to reject the hypothesis test of no random effects (p-value <.0001) implying significant inter-hospital differences.

To assess the need to include interactions, we fitted a series of models starting from a main effects model (M1) and successively introducing interaction variables. Although statistically significant interaction terms were present, we retained the main effects model as the "initial model" starting point of our sensitivity analysis. Our choice was guided by the ease of its interpretation and by the modest improvement by adding interaction terms in the modeling (see Additional file: Modeling CAP mortality). The scaled Pearson statistic for the conditional distribution (0.95) did not suggest a problem of over- or under-dispersion.

Recognizing the limitations of administrative data regarding selection bias, inadequate risk-adjustment, and other biases indirectly arising from differences in medical practices and in attitudes, including (1) whether or not providing IMV/NMV, (2) early discharging patients (especially of terminal patients), (3) artificially increasing the case-mix and (4) withholding optimal care for the elderly, whether or not by request of patient or family, we tried to take these biases into account by carrying out a sensitivity analysis. Therefore we constructed two models, excluding from the analysis patients discharged during the first week (as a proxy for early discharge) and patients aged over 79 years, respectively. Subsequently, we fitted two additional models, in which no adjustment was made for intensity of care and co-morbidities, respectively.

Moreover, random intercepts are believed to remove some of the biases typical of hospital-based registries as a result of differences including case-definition, case-ascertainment, coding, and SES [17]. Also, the choice of analyzing a cause-specific SMR is considered more-reliable than that of a hospital-wide one [18].

Alternative statistical approaches in the domain of CAP-related mortality, e.g. risk prediction models [4] and data driven rules to predict mortality [5], could not be applied due to the absence of recommended severity scores, laboratory data and physiologic information in our data.

Funnel plots

We generated scatter plots of the hospitals' SMR, against the number of admitted patients (the "volume"). The vertical and horizontal axes of the plot represent the values of the SMR and of the volume, respectively, with 99.8% and 95% control limits. Taking the possible confounding effects of unmeasured or mismeasured variables into account [19], we delimited an *inconclusive zone* (shaded on the graphs), including all SMRs in the range between 33% above and 25% below the reference SMR of 100. This zone was intended to facilitate the detection of false negative results in small hospitals and false positive results in large hospitals[20]. The fitted model and the event ratio of the "average Belgian hospital" are displayed in footnotes.

Given these limits five performance categories are usually[16, 20; 21] defined, ranging from 'action' (above or equal to the upper bound of the 99.8% limits); over 'alarm' (above or equal to the upper bound of the 95% limits, but lower than the upper bound of the 99.8% limits), 'normal', 'good' (below or equal to the lower bound of the 95% limits, but higher than the lower bound of the 99.8% limits); to 'excellent' (below or equal to the lower bound of the 99.8% limits).

However, to interpret the results of the sensitivity analysis we defined a hospital's performance as 'To be assessed' when the performance category changed by more than 1 contiguous category. Otherwise, if the performance category equaled 'Excellent' or 'Action' in one of the analyses, we labeled the hospital 'Possibly better' or 'Possibly worse'

performing, respectively. Hospitals belonging to the categories “Action” or “Excellent” are numbered in the figures. A further ‘To be assessed’ category, consisted of hospitals, which were found in sensitivity analysis at least once outside the inconclusive zone. A final, ‘Normally performing’, category encompassed the remaining hospitals. All analyses were carried out in SAS 9.2. The program code used to create the funnel plots is freely available from the authors.

The study being (1) of a retrospective, non-interventional type and (2) anonymous with respect to patients, no approval by an ethics committee is required under the Belgian law.

RESULTS

Patient and hospital characteristics

The mortality proportion in the MCD *inter-hospital* study population amounted to 12.13% (95%CI: 11.93-12.32) overall, 12.88 % (95%CI: 12.62-13.15) in males, and 11.15% (95%CI: 10.87-11.44) in females. In case of ARF, the mortality proportion amounted to 37.62% (95%CI: 35.67-39.61) in males and 34.63% (95%CI: 32.32-37.01) in females.

In both sexes we observed the highest admission numbers (more than 50%) in the age window of 70-89 years and increasing mortality ratios with increasing age (Table 1). Conversely, although higher in deceased patients of both sexes, IMV markedly decreased with increasing age: from about 40% in age-class 40-49y to 20% in age-class 80-89y.

The volume of patients admitted varied hugely between hospitals.

Adjusted odds ratios (Table 2), showed the paramount importance of old age, multiple co-morbidities and IMV. Small volume, admission from another hospital or from a rest & nursing home, and, to a lesser extent, the male sex, weekend admissions and admissions in non-teaching hospitals showed higher mortality ratios. LOS displays a J-shaped relationship with mortality.

Validity of the data

Comparing MCD's estimate of the in-hospital 30-day mortality rate with the Carenet data, we obtained quite similar overall and age-specific figures (Figure 1). In addition, striking similarities between the Belgian and German data were observed regarding in-hospital age distribution, age-specific incidence rates, and age-specific mortality proportions (Figure 1).

Finally, an on-site audit on 4093 medical files concluded that the auditor agreed in the large majority of cases (82%) with the coded hospital diagnosis. In another 14% of cases the coded hospital diagnosis seemed still to deserve a "CAP likely" type of conclusion, whereas

in 4% of the cases the auditor assigned a code to the principal diagnosis, corresponding to another, clearly not CAP-related pathology. The type of conclusion, however, considerably varied across hospitals.

Inter-hospital comparison

According to our definitions, 5 hospitals were classified as "Possibly better performing", 7 as "Possibly worse performing", 18 as 'To be assessed' and 81 as "Normally performing" (Table 3). To somewhat facilitate the interpretation, we also provided the registered intensity of care, by category, as well as the corresponding national percentages. The five hospitals of supposedly 'better' quality found themselves in the sensitivity analyses most often below the inconclusive zone (Figure 2), suggesting a real survival excess. Six hospitals, labeled as 'possibly worse' performing, presented the opposite image, suggesting a real mortality excess. No single potential starting point for improvement became apparent, with the exception of underuse of IMV/NMV in hospital 37 combined with a lower SMR in the intensity-of-care-excluded-analysis. A seventh hospital (number 62), deserves a more cautious interpretation since it exclusively treats cancer patients. This may largely explain its extreme position in the basic analysis, as well as the huge SMR in the CCI- excluded-analysis and the less intensive care provided.

DISCUSSION

As a starting point for a national indicator project [22], our study unveiled considerable inter-hospital differences in CAP-SMR, suggesting real differences in quality of care, that deserve further investigation.

In an effort to facilitate the interpretation of the findings and to reduce biases we carried out a sensitivity analysis and superposed an inconclusive zone on the funnel plot.

Adding an inconclusive zone to the funnel plot may not only help to reveal the presence of both false positive and false negative outliers but, more importantly, it takes into account the magnitude of the SMR's departure. The choice of the limits was inspired by the literature [19] and may find some support in the divergent male versus female ORs in our and the German study [3].

The sensitivity analysis on the other hand allowed us to a certain extent (1) to disentangle therapeutic attitudes from quality of care, and (2) to remove some of the biases due to inadequate risk-adjustment and to gaming. For instance a model not adjusted for mechanical ventilation - a resource-intensive procedure shown to be recorded most accurately [23] - may induce a change of quality towards a lesser category, thus suggesting good quality, a finding that may be confirmed by the registered intensity of care. Similarly, the exclusion of LOS less than 8 days, resulting in a labeling of lesser quality may be related to gaming by discharging past saving patients [2,24] and is susceptible to induce bias into the in-hospital mortality comparisons due to differential follow-up [25]. Alike, through the exclusion of patients aged 80+ or by withdrawing co-morbidity from the modeling, an attempt was made to assess the possible effects on the SMRs respectively of therapeutic attitudes as well as patient or next of kin wishes [3], or of up-coding phenomena.

Both techniques added value to the initial model of our inter-hospital analysis, that resulted in the identification of five and six outlying hospitals as respectively providing possibly better or worse care. These 11 hospitals, identified as outliers, found themselves consistently on the extremes of the SMR distribution and often outside the inconclusive zone. Given the 99.8% control limits and although no over-dispersion was present, the number of 11 hospitals identified as 'out-of-control' is higher than the expected 0.2% risk of a false alarm (21), suggesting we are dealing with a number of really outlying hospitals within this group. We feel that way to have (1) considerably overcome biases due to inadequate risk-adjustment and to gaming, common in administrative data, and (2) taken differences in therapeutic attitudes into account.

Furthermore our approach disclosed possible quality weaknesses or strengths for some of the 18 hospitals, labeled 'To be assessed'. According to the funnel plot of the initial model (Figure 2 and Table 3) only, three (35, 44, 45) of them could be labeled 'excellent'. However, based on our pre-set definitions (see methods section) these hospitals fall in the 'to-be-assessed' category, notwithstanding their barely changing SMRs. This may be due to the influence of the sample size on the control limits by excluding observations (patients aged 80 years and more or LOS less than 8 days), to therapeutic attitudes regarding the provision of certain types of care to elderly patients (hospital 44), to discharge practices (hospital 45) or due to the removal of an adjustment (intensity of care in hospital 35). For similar reasons hospital 10, to be labeled as 'Good' according to the funnel plot and finding itself below the inconclusive zone, is rated 'to-be-assessed'. Although within the inconclusive zone, two large-size hospitals (71 and 89) are labeled as deserving 'Action', which may be due to a suboptimal use of mechanical ventilation, suggested by the 'Intensity-of care-excluded-analysis'. Seven hospitals (4, 14, 19, 23, 43, 55 and 95) designated as 'Alarm' or 'Action' and 4 hospitals (9, 47, 81and 106) accredited as 'Normal' in the initial model, received no clue for

improvement from the sensitivity analysis. Hospital 29, labeled ‘Normal’ on four sub-analyses, had four times an ‘SMR below the inconclusive zone’, suggesting better quality.

Since pneumonia care may be provided in an out-patient setting, selection biases [26] may occur and require a cautious interpretation of the in-hospital findings. However, the striking resemblance between the MCD and German Hospital data, the similarity between MCD and Carenet data concerning both the overall and the age-specific in-hospital mortality, and the results of the audit are reassuring for the validity of the data regarding mortality in hospitalized CAP patients and its determinants.

In addition to the already discussed biases we faced several study limitations, including the lack of laboratory results, of radiological and of clinical findings such as mental confusion and severity of illness [27, 28]. Although ’intensity of care’ may perform well as a proxy for severity of illness (9), the completeness of its registration in our administrative data remains uncertain. The preceding encouraged us to label our inter-hospital results a ‘screening’, that has to be further investigated, rather than ‘assessing’ quality of care.

Adding a sensitivity analysis and introducing an inconclusive zone into the analysis may be considered strengths of our study. Also the observed adjusted mortality ORs according to age, co-morbidity and invasive ventilator support are congruous with the literature[3, 26, 29]. The gender divide in favor of the females is rather small but in accordance with two sizable cohort studies[26, 30] but is absent in another one [3]. Our finding of a doubled mortality risk in patients admitted from a rest & nursing home, conceivably at risk of Healthcare Associated Pneumonia (HCAP), is in line with the literature [29, 31]. By selecting pneumonia as principal diagnosis, we avoided to include cases of nosocomial pneumonia that should be

coded as secondary diagnoses. We further excluded short-term fatalities to avoid potential hospital-bias related to early unavoidable deaths [10].

Though, we did not find direct clues to assess specific departures from evidence-based practices, our sensitivity analysis tentatively indicated areas of possible betterment. In addition, the sizeable inter-hospital differences suggested real differences in quality of care. As a first step to quality improvement, monitoring of CAP-SMRs seems needed to assess whether this quality divide is fading away.

Appendix 1: Scoring the co-morbidity index from secondary diagnoses by the Charlson's co-morbidity index, D'Hoore implementation [8] (CCI).

Weights	Conditions	ICD-9 codes
1	Myocardial infarction	410, 411
	Congestive heart failure	398, 402, 428
	Peripheral vascular disease	440 – 447
	Dementia	290, 291, 294
	Cerebro-vascular disease	430 – 433, 435
	Chronic pulmonary disease	491 – 493
	Connective tissue disease	710, 714, 725
	Ulcer disease	531 – 534
	Mild liver disease	571, 573
2	Hemiplegia	342, 434, 436, 437
	Moderate or severe renal disease	403, 404, 580 - 586
	Diabetes	250
	Any tumor	140-195
	Leukaemia	204 - 208
	Lymphoma	200, 202, 203
3	Moderate or severe liver disease	070, 570, 572
6	Metastatic solid tumor	196 – 199

Appendix 2: Identification of pneumonia cases, Intensity of care and Acute respiratory failure by means of ICD-9-CM and ICD-9 related text strings

1. Definition of CAP-cases in MCD

Building on the work of the Agency for Healthcare Research and Quality (AHRQ)[7] we selected, for the years 2004-2007, from the Minimal Clinical Data all stays having Community Acquired Pneumonia as principal diagnosis. We adopted the AHRQ definition of pneumonia (Inpatient Quality Indicator 20)[7]: "Hospitalized patients with a *principal diagnosis* of pneumonia to the exclusion of patients with missing discharge disposition, transferring to another short-term hospital ,Major Diagnostic Categories (MDC) 14 (pregnancy, childbirth, and puerperium),MDC 15 (newborns and other neonates)" and patients less than 18 years. However, in close consultation with clinicians we decided to adapt the AHRQ selection of the ICD-9-CM codes, used to identify cases of pneumonia, to the Belgian situation.

Our selection included following codes:

4808	VIRAL PNEUMONIA NEC	48289	BACT PNEUMONIA NEC
4809	VIRAL PNEUMONIA NOS	4829	BACTERIAL PNEUMONIA NOS
481	PNEUMOCOCCAL PNEUMONIA	4830	MYCOPLASMA PNEUMONIA
4820	K. PNEUMONIAE PNEUMONIA	4831	CHLAMYDIA PNEUMONIA OCT96-
4821	PSEUDOMONAL PNEUMONIA	4838	OTH SPEC ORG PNEUMONIA
4822	H.INFLUENZAE PNEUMONIA	4841	PNEUM W CYTOMEG INCL DIS
48230	STREP PNEUMONIA UNSPEC	4843	PNEUMONIA IN WHOOP COUGH
48231	GRP A STREP PNEUMONIA	4845	PNEUMONIA IN ANTHRAX
48232	GRP B STREP PNEUMONIA	4846	PNEUM IN ASPERGILLOSIS
48239	OTH STREP PNEUMONIA	4847	PNEUM IN OTH SYS MYCOSES
4824	STAPHYLOCOCCAL PNEUMONIA	4848	PNEUM IN INFECT DIS NEC
48240	STAPH PNEUMONIA UNSP OCT98-	485	BRONCOPNEUMONIA ORG NOS
48241	STAPH AUREUS PNEUMON OCT98-	486	PNEUMONIA, ORGANISM NOS
48249	STAPH PNEUMON OTH OCT98-	5070	FOOD/VOMIT PNEUMONITIS
48281	ANAEROBIC PNEUMONIA	5100	EMPYEMA WITH FISTULA
48282	E COLI PNEUMONIA	5109	EMPYEMA W/O FISTULA
48283	OTH GRAM NEG PNEUMONIA	5110	PLEURISY W/O EFFUS OR TB
48284	LEGIONNAIRES DX OCT97-	5130	ABSCESS OF LUNG

2. Intensity of care
   Invasive mechanical ventilation (IMV): 96.7*, 96.04, 97.37
   Non-invasive mechanical ventilation (NMV):93.9*

3. Acute respiratory failure (ARF): 518.81, 518.82

4. List of text strings used to identify community acquired pneumonia cases from the discharge field in the CARENET database

ICD 9 code	**Condition**	**Search strings used in SQL in brackets, % is a wildcard***
460-486	Pneumonia excluding influenza	'%PNEUMONI%'; '%LONGONT%'; '480%'; '481%'; '482%; '483%'; '484%'; '485%'; '486%' '% 480%'; '% 481%'; '% 482%; '% 483%'; '% 484%'; '% 485%'; '% 486%';
510.0	Empyema within the respiratory system, with mention of fistula	'%EMPYEMA%'; '5100%'; '% 5100%'; '510.0%'; '% 510.0%';
510.9	Empyema within the respiratory system, without mention of fistula	'%EMPYEMA%'; '5109%'; '% 5109%'; '510.9%'; '% 510.9%';
513.0	Abscess of the lung	'5130%'; '% 5130%'; '513.0%'; '% 513.0%';

1. * A wildcard '%' stands for any series of characters. Using wildcards is necessary because of the presence of multiple diagnoses and the combination of text and ICD9 coding within the Carenet discharge field.

Appendix 3: The Carenet hospitalization database

The Carenet data is constructed under the initiative of the seven sickness funds in Belgium and operates independently from the MCD database. Hospitals that choose to participate in Carenet, provide hospitalisation records including primary and secondary diagnoses, patient and hospital identifiers and time and date of hospitalisation. The proportion of included hospitals in the database has grown substantially during the study period, from 11% of hospital beds in 2004 to 91% in 2007.

For each recorded hospitalization, a discharge record includes a list of primary and optional secondary diagnoses as free text fields, which usually includes ICD9-coding or diagnoses in text. In this diagnosis field, we performed a text string search to identify CAP cases with pneumonia based on ICD9 code or the text string (see Appendix 2).

For members of the National Alliance of Christian Sickness Funds (NACSF), one of the seven sickness funds, we linked CAP hospitalisations to patient characteristics (age, gender and survival). The NACSF membership, about 44% of the Belgian population, shows a slight overrepresentation of the older age groups and a small under-representation of the unemployed.

All analyses based on the joint information in the Carenet and NACSF internal databases were performed at NACSF under supervision of a social security physician.

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Competing interests

The author(s) declare that they have no competing interests relevant to the content of this paper.

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Authors' contributions

WA conceived of the study, drafted the manuscript, and participated in the design of the study and in the statistical analysis. NT carried out the extraction of the MCD data and participated in the analysis. AB carried out the extraction and the analysis of the Carenet data, wrote part of the methodology section and of the statistical methodology. GM and NH advised on the statistical methodology and data analysis. FDS and MC acquired and interpreted the Carenet

data. PB helped in the design of the study, interpreting the results and revising earlier drafts. All authors critically revised and approved the final version of the manuscript.

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Table 1: Distribution of patient, stay and hospital characteristics for the *inter-hospital* study population

Inter-hospital study population (N=108,213)												
	Males						Females					
	Dec.	Cases	OR	95% CI		Col%	Dec.	Cases	OR	95% CI		Col%
Intensity of care												
I MV	2357	4151	12.69	11.85	13.59	7	1314	2524	11.52	10.57	12.55	5
NIMV	871	7530	1.26	1.17	1.36	12	561	5302	1.26	1.14	1.38	11
Basic care	4614	49193	1	.	.	81	3404	39513	1	.	.	83
ARF												
Yes	895	2379	4.47	4.10	4.88	4	562	1623	4.47	4.10	4.88	3
No	6947	58495	1	.	.	96	4717	45716	1	.	.	97
CCI												
0	913	16932	0.15	0.13	0.16	28	927	17010	0.17	0.14	0.19	36
1	1195	13298	0.25	0.23	0.28	22	852	10092	0.27	0.23	0.31	21
2	1232	9462	0.38	0.35	0.42	16	978	7527	0.43	0.38	0.50	16
3	1154	7201	0.49	0.44	0.54	12	787	4821	0.57	0.49	0.65	10
4	855	4222	0.65	0.58	0.72	7	486	2823	0.60	0.51	0.71	6
5	533	2439	0.71	0.63	0.81	4	348	1531	0.85	0.72	1.01	3
6	435	1628	0.93	0.81	1.06	3	227	881	1.01	0.83	1.22	2
7	250	876	1.02	0.86	1.20	1	134	488	1.10	0.87	1.39	1
8	242	1062	0.75	0.64	0.89	2	143	569	0.97	0.78	1.22	1
9	192	771	0.84	0.70	1.01	1	66	307	0.79	0.59	1.07	1
10+	841	2983	1	.	.	5	331	1290	1	.	.	3
Age class												
< 40 y	49	4967	1	.	.	8	40	4767	1	.	.	10
40-49y	112	3912	2.96	2.11	4.15	6	70	3080	2.75	1.86	4.06	7
50-59y	357	6144	6.19	4.58	8.37	10	174	4293	4.99	3.53	7.06	9
60-69y	933	9798	10.56	7.91	14.11	16	331	5417	7.69	5.53	10.70	11
70-79y	2472	17358	16.67	12.54	22.15	29	1158	10302	14.97	10.90	20.55	22
80-89y	3079	15430	25.02	18.83	33.24	25	2311	14093	23.18	16.93	31.74	30
90-99y	824	3214	34.61	25.83	46.35	5	1147	5231	33.19	24.15	45.62	11
100y+	16	51	45.88	23.83	88.33		48	156	52.52	33.13	83.28	
Admitted from												
Hospital	345	1531	2.25	1.99	2.55	3	224	1002	3.02	2.59	3.52	2
Rest&Nursing home	1410	6059	2.35	2.20	2.51	10	1745	8442	2.73	2.56	2.91	18
Other	154	1360	0.99	0.84	1.17	2	74	746	1.15	0.91	1.47	2
Home	5933	51924	1	.	.	85	3236	37149	1	.	.	78
Weekend admission												
Yes	1708	13126	1.01	0.96	1.07	22	1213	10151	1.11	1.03	1.18	21
No	6134	47748	1	.	.	78	4066	37188	1	.	.	79
LOS(in days)												
0	0	941	n/a	n/a	n/a	5	0	666	n/a	n/a	n/a	5
1	0	762	n/a	n/a	n/a	4	0	543	n/a	n/a	n/a	4

2	0	1089	n/a	n/a	n/a	5	0	731	n/a	n/a	n/a	5
3	501	2338	3.25	2.80	3.77	12	346	1707	3.06	2.57	3.64	12
4	386	3152	1.66	1.43	1.94	16	364	2343	2.21	1.87	2.63	16
5	387	3423	1.52	1.30	1.77	17	284	2513	1.53	1.28	1.83	18
6	380	3797	1.32	1.14	1.54	19	242	2589	1.24	1.03	1.49	18
7	340	4391	1	.	.	22	250	3258	1	.	.	23
Subtotal	1994	19893					1486	14350				
LOS (in weeks)												
0	1994	19893	0.30	0.28	0.32	33	1486	14350	0.45	0.41	0.49	30
1	1937	21926	0.26	0.24	0.28	36	1336	16911	0.33	0.31	0.36	36
2	1337	8743	0.49	0.45	0.53	14	878	7573	0.51	0.46	0.56	16
3	901	4130	0.75	0.69	0.83	7	564	3544	0.74	0.66	0.82	7
4+	1673	6182	1	.	.	10	1015	4961	1	.	.	10
Teaching hospital												
Yes	465	4123	1	.	.	7	317	2960	1	.	.	6
No	7377	56751	1.18	1.06	1.30	93	4962	44379	1.05	0.93	1.18	94
All patients												
Males	7842	60874	1.18	1.14	1.22							
Females	5279	47339										

Hospital volume in quintiles	Nbr of hospitals	Minimum	Maximum	Range
Q1	22	171	510	339
Q2	21	518	696	178
Q3	23	697	928	231
Q4	22	938	1327	389
Q5	23	1359	3651	2292

Dec.: deceased; OR: odds ratio; **95% CI**: ninety five percent confidence interval, rounded to the nearest unit; **Col%**: column percent. ARF: Acute Respiratory Failure as principal diagnosis; IMV: Invasive mechanical ventilation ; **n/a**: not applicable; NIMV : non-invasive mechanical ventilation ;Volume : number of admissions with CAP as principal diagnosis.

Table 2: Adjusted OR and 95% CI (1) of mortality determinants, and (2) fixed effects part of the inter-hospital comparison, initial model.

		Determinants of inter-hospital comparison			Fixed effects of Inter-hospital comparison		
		OR	95%CI		OR	95%CI	
Age class	100y+ vs < 40y	54.68	37.57	79.58	42.58	29.34	61.79
	90-99y vs < 40y	32.32	25.87	40.37	24.76	19.81	30.95
	80-89y vs < 40y	19.59	15.76	24.34	15.10	12.14	18.78
	70-79y vs < 40y	10.61	8.54	13.19	8.49	6.82	10.56
	60-69y vs < 40y	5.7	4.56	7.12	4.74	3.79	5.93
	50-59y vs < 40y	3.44	2.73	4.35	2.99	2.36	3.78
	40-49y vs < 40y	1.97	1.51	2.56	1.81	1.39	2.36
Gender	Males vs Females	1.25	1.2	1.31	1.27	1.22	1.33
CCI	CCI 10 vs 0	6.62	6.03	7.28	6.10	5.56	6.70
	CCI 9 vs 0	3.28	2.76	3.89	3.08	2.61	3.65
	CCI 8 vs 0	3.53	3.07	4.07	3.34	2.90	3.84
	CCI 7 vs 0	3.19	2.75	3.7	3.00	2.60	3.47
	CCI 6 vs 0	3.07	2.74	3.45	2.84	2.53	3.18
	CCI 5 vs 0	2.34	2.12	2.59	2.15	1.95	2.38
	CCI 4 vs 0	2.08	1.91	2.27	1.94	1.79	2.11
	CCI 3 vs 0	1.82	1.69	1.97	1.69	1.57	1.82
	CCI 2 vs 0	1.56	1.45	1.68	1.47	1.37	1.58
	CCI 1 vs 0	1.15	1.07	1.23	1.08	1.01	1.16
Admission	Hosp. vs Home	1.92	1.71	2.16	1.91	1.70	2.14
	R &N home vs Home	1.79	1.7	1.89	1.72	1.64	1.82
	Other place vs Home	1.14	0.97	1.34	1.15	0.98	1.35
Intensity of care	IMV vs Basic	14.88	13.94	15.88	14.31	13.45	15.22
	NMV vs Basic	1.29	1.2	1.39	1.24	1.16	1.33
LOS (weeks)	Week' 0 vs 4+'	1.48	1.38	1.58	.	.	.
	Week '1 vs 4+'	0.61	0.57	0.65	.	.	.
	Week '2 vs 4+'	0.71	0.66	0.76	.	.	.
	Week '3 vs 4+'	0.92	0.85	1	.	.	.
Volume	Quintile' 1 vs 5'	1.04	0.88	1.24	.	.	.
	Quintile' 2 vs 5'	1	0.85	1.18	.	.	.
	Quintile' 3 vs 5'	1.12	0.95	1.31	.	.	.
	Quintile' 4 vs 5'	1.17	0.99	1.38	.	.	.
WE admission	Yes vs No	1.03	0.98	1.09	.	.	.
Teaching	Yes vs No	0.78	0.62	0.98	.	.	.

CCI: Charlson's Comorbidity Index; R &N home: Rest & Nursing home; IMV/NMV: invasive/non-invasive mechanical ventilation; OR: Odds ratio; 95% CI: 95% confidence interval.

Table 3: Results of the sensitivity analysis of hospitals, deserving particular attention regarding the quality of care provided: SMR, funnel plot (Plot) and inconclusive zone (Zone), for each of the analyzed models

Id	Model														Volume	Quality	Registered Intensity of Care (%)		
	Initial model			LOSses <8 excluded			Patients 80y+ excluded			Intensity of Care excluded			CCI excl.							
	SMR	Plot	Zone	SMR	Plot	Zone	SMR	Plot	Zone	SMR	Plot	Zone	SMR	Plot	Zone			I	NI	B
16	71	E	Y	73	E	Y	75	E	N	74	E	Y	82	E	N	5	Better	8	23	69
21	72	E	Y	76	G	N	75	G	Y	71	E	Y	72	E	Y	4	Better	3	69	28
33	61	E	Y	62	E	Y	68	G	Y	57	E	Y	63	E	Y	4	Better	5	22	73
34	78	E	N	85	G	N	75	G	Y	75	E	Y	77	E	N	5	Better	5	29	66
105	71	E	Y	68	E	Y	63	E	Y	63	E	Y	75	E	Y	5	Better	4	2	94
7	126	Ac	N	119	Al	N	139	Ac	Y	134	Ac	Y	130	Ac	N	4	Less	9	4	87
15	137	Ac	Y	150	Ac	Y	139	Al	Y	151	Ac	Y	127	Al	N	3	Less	7	21	72
37	211	Ac	Y	206	Ac	Y	238	Ac	Y	143	Al	Y	205	Ac	Y	1	Less	0	0	100
52	128	Ac	N	124	Al	N	130	Al	N	148	Ac	Y	139	Ac	Y	4	Less	11	1	89
62	215	Ac	Y	223	Ac	Y	230	Ac	Y	152	Al	Y	365	Ac	Y	1	Less	1	4	95
73	139	Ac	Y	137	Ac	Y	138	Al	Y	133	Ac	Y	152	Ac	Y	4	Less	7	3	91
88	130	Ac	N	131	Al	N	145	Al	Y	127	Al	N	121	Al	N	3	Less	5	13	82
4	125	Al	N	117	N	N	118	N	N	164	Ac	Y	127	Ac	N	4	Assess	15	3	82
9	95	N	N	100	N	N	129	Al	N	83	G	N	96	N	N	4	Assess	2	0	97
10	61	G	Y	69	N	Y	82	N	N	56	E	Y	54	E	Y	1	Assess	3	16	82
14	118	Al	N	105	N	N	117	N	N	133	Ac	Y	124	Ac	N	5	Assess	10	30	60
19	137	Ac	Y	131	Al	N	118	N	N	153	Ac	Y	139	Ac	Y	2	Assess	9	4	87
23	117	Al	N	115	N	N	111	N	N	126	Ac	N	115	Al	N	5	Assess	8	1	91
29	66	G	Y	70	N	Y	70	N	Y	68	N	Y	72	N	Y	1	Assess	6	10	84
35	70	E	Y	77	G	N	64	E	Y	88	N	N	76	E	N	5	Assess	12	9	78
43	119	Al	N	117	Al	N	134	Ac	Y	108	N	N	114	Al	N	5	Assess	4	2	94

44	76	E	N	83	G	N	80	N	N	75	E	N	78	E	N	5	Assess	6	1	93
45	70	E	Y	85	N	N	69	G	Y	64	E	Y	68	E	Y	3	Assess	3	24	73
47	114	N	N	110	N	N	112	N	N	128	Ac	N	116	N	N	4	Assess	9	5	86
55	122	Al	N	120	Al	N	116	N	N	117	Al	N	124	Ac	N	4	Assess	5	5	90
71	121	Ac	N	114	Al	N	136	Ac	Y	107	N	N	123	Ac	N	5	Assess	4	0	96
81	114	N	N	114	N	N	101	N	N	129	Ac	N	125	Al	N	4	Assess	8	82	9
89	124	Ac	N	125	Al	N	119	N	N	111	N	N	123	Ac	N	5	Assess	3	0	97
95	127	Al	N	123	N	N	133	N	N	141	Ac	Y	122	N	N	1	Assess	9	8	83
106	119	N	N	117	N	N	129	N	N	145	Ac	Y	121	N	N	2	Assess	12	4	85
Nat.																		6	12	82

Id: anonymous hospital identifier; **LOSses <8 days**: the model wherein observations with LOSses of less than 8 days are excluded**; Patients 80y+ excluded**: the model wherein patients aged 80 years or more are excluded; **Intensity of Care excluded**: the model not adjusted for intensity of care; **CCI excluded**: the model not adjusted for CCI; **SMR**: Standardized Mortality Ratio, rounded to the nearest unit; **P:** conclusion based on control limits of the funnel plot (E: excellent; G:good; Al: alarm; Ac: action; N: normal); **Zone**: SMR outside the inconclusive zone (Y: yes / N:no) ; **Volume:** Volume in terms of quintiles; **Quality**: Better/Less: possibly better/less performing hospital - Assess: to be assessed performance. **Registered intensity of care (%):** registered intensity of care (expressed in %) as carried out in the individual hospitals and nationally (displayed in the row 'Nat': 'National') (I: Invasive mechanical ventilation; NI: non-invasive mechanical ventilation; B: basic care).

Figure 1: Validity of the data: (a) Comparison of the in-hospital 30-days mortality rate (in %) between the Carenet and MCD registries (upper left panel); (b) Comparison of in-hospital CAP admissions between MCD and Germany (Ge) in (1) incidence (in %) (upper right panel), in age class distribution (in %) (lower left panel), and (3) mortality rates (in %) (lower right panel)

Comment [PB1]: De assen zijn moeilijk leesbaar, kan je die groter maken ?

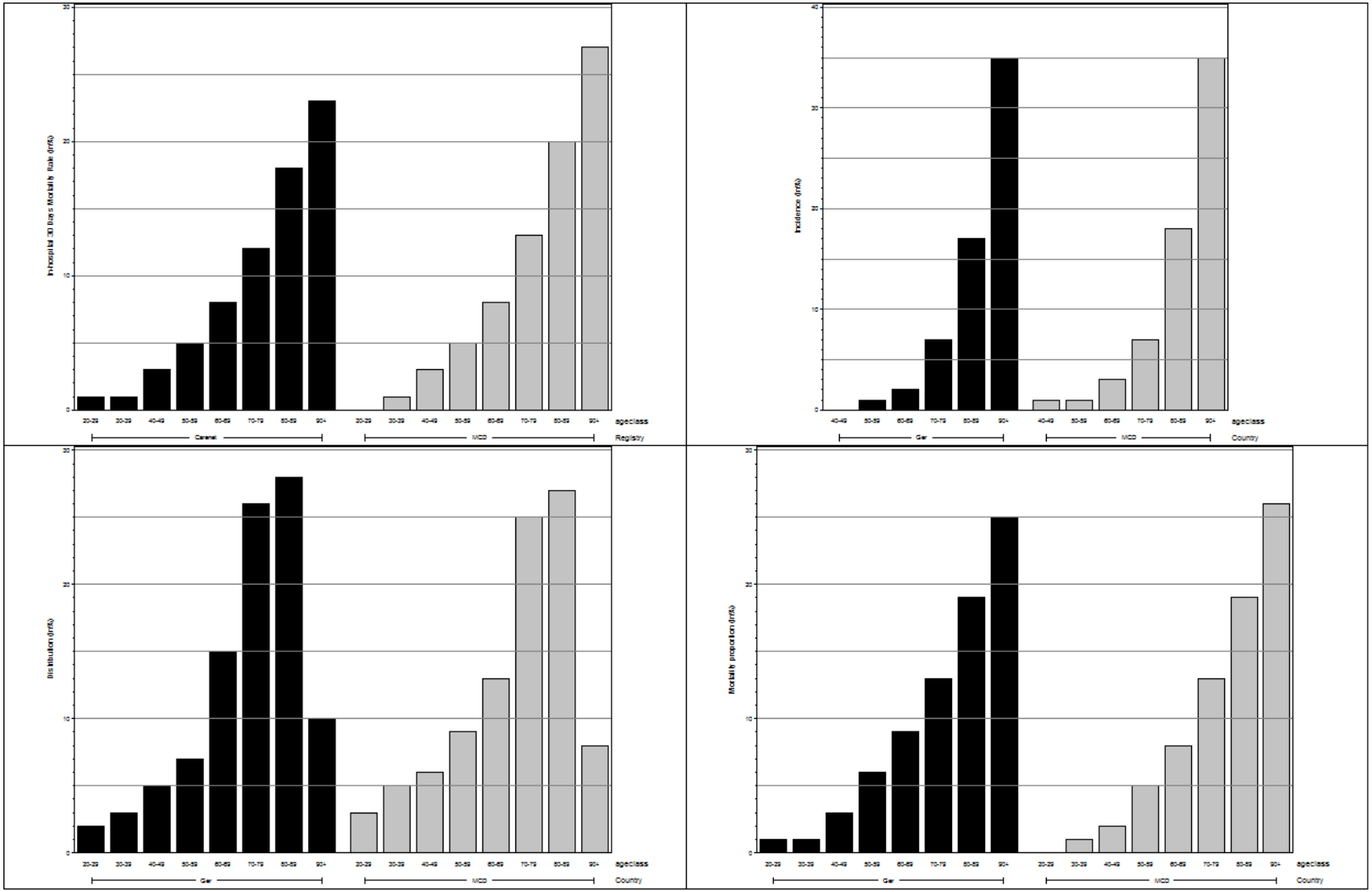
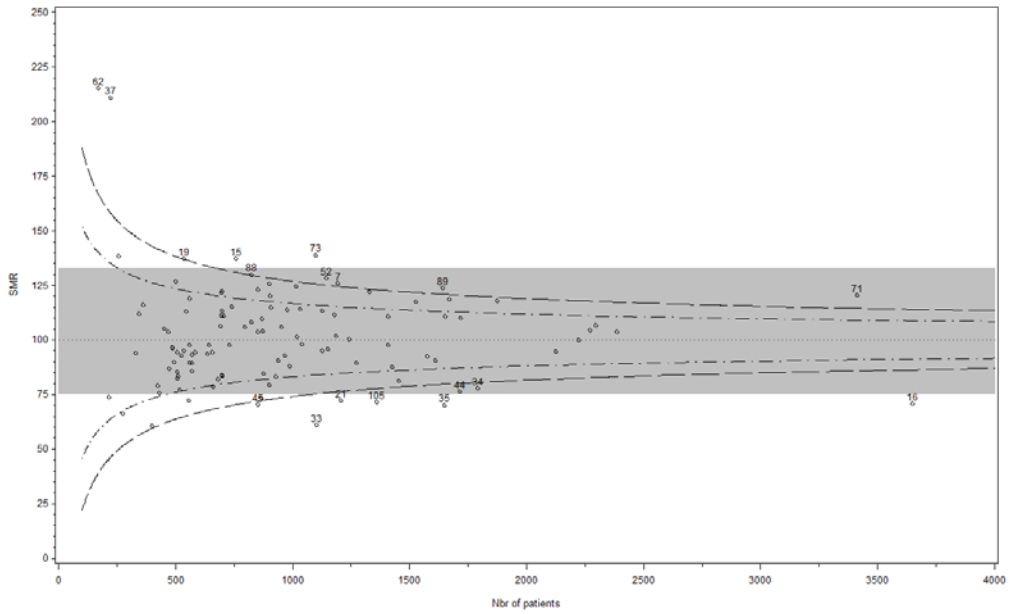
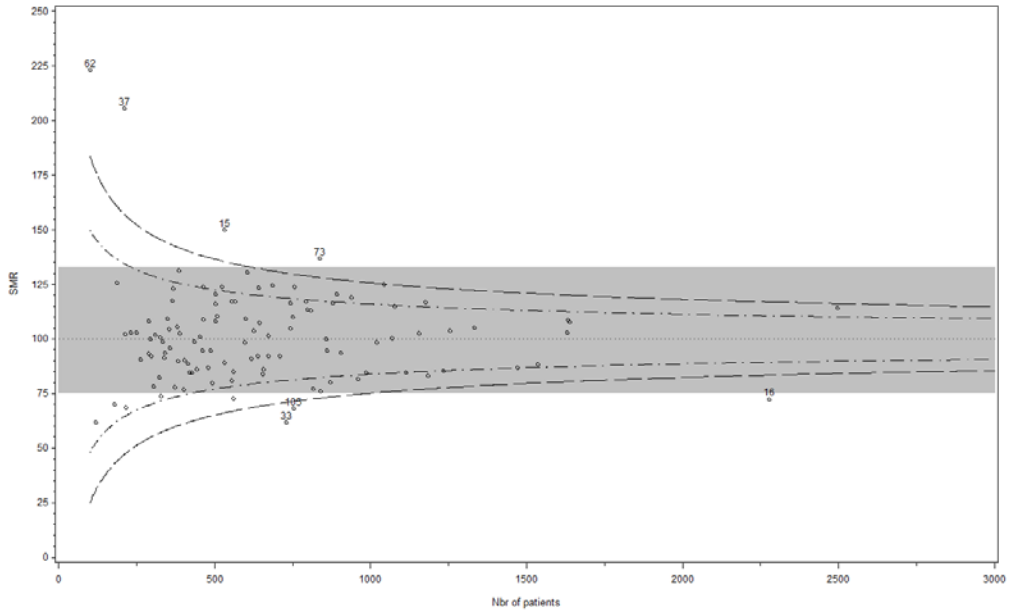

Incidence (/mN)
ageclass
Registry
Incidence (/mN)
ageclass
Country
Distribution (/mN)
ageclass
Country
Mortality proportion (/mN)
ageclass
Country

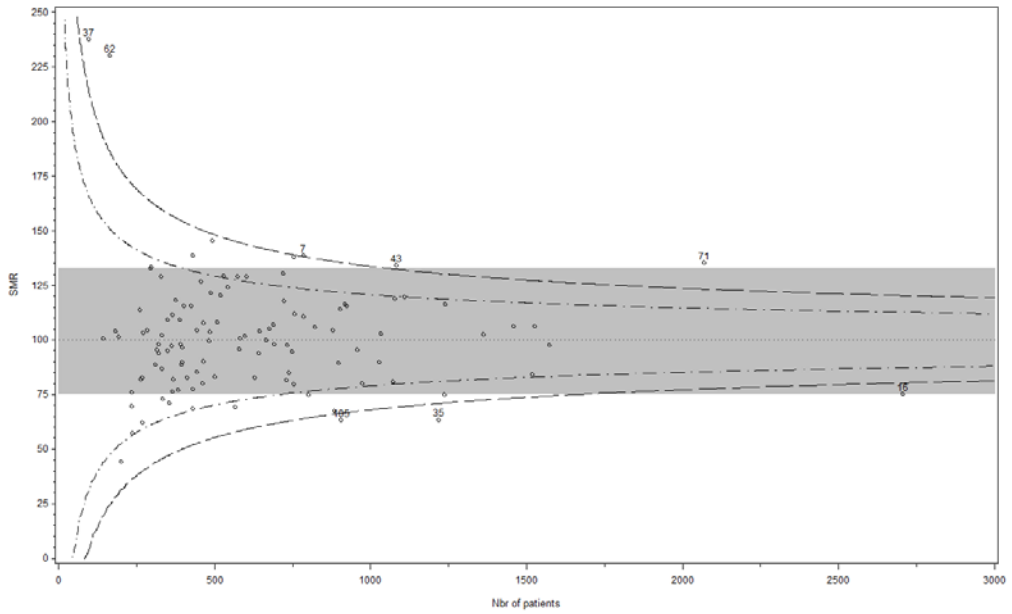
Figure 2: Funnel plots based on the results of the sensitivity analysis: from top to bottom: (1) the initial model, (2) the model in which observations with LOS < 8 days are excluded, (3) the model in which patients aged 80 years or more are excluded, (4) the model not adjusted for intensity of care, and (5) the model not adjusted for CCI. Inner and outer dashed lines are respectively 95% and 99.8% control limits, derived using the "interpolated", exact binomial distribution. The inconclusive zone (shaded on the graphs) extends from 25% below to 33% above the reference SMR of 100 (dotted line). (Numbered) circles represent (outlying outside the 99.8% control limits) hospitals.

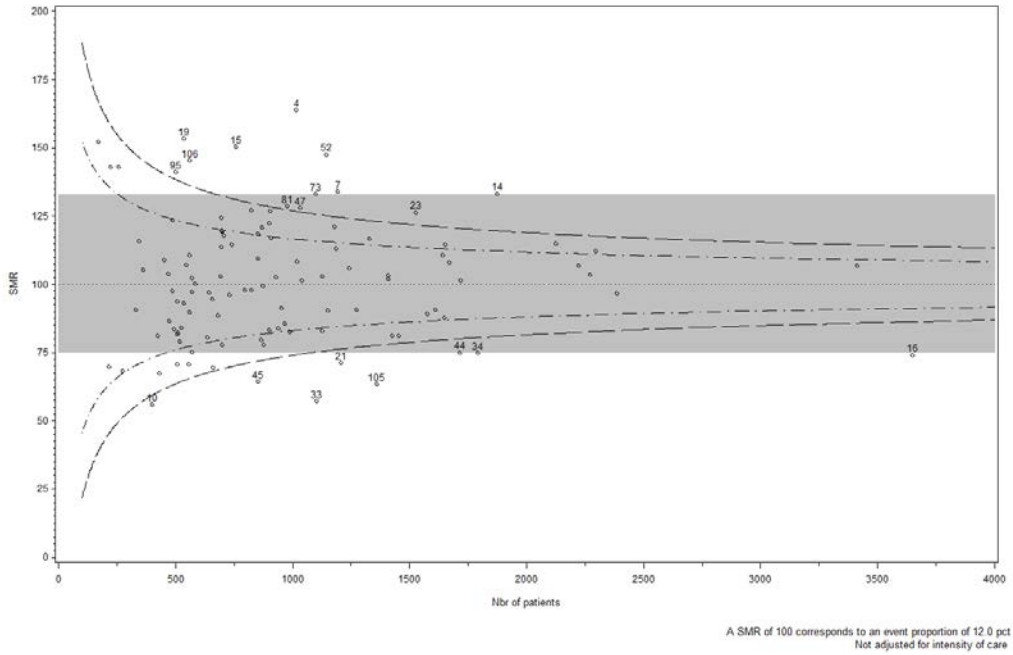


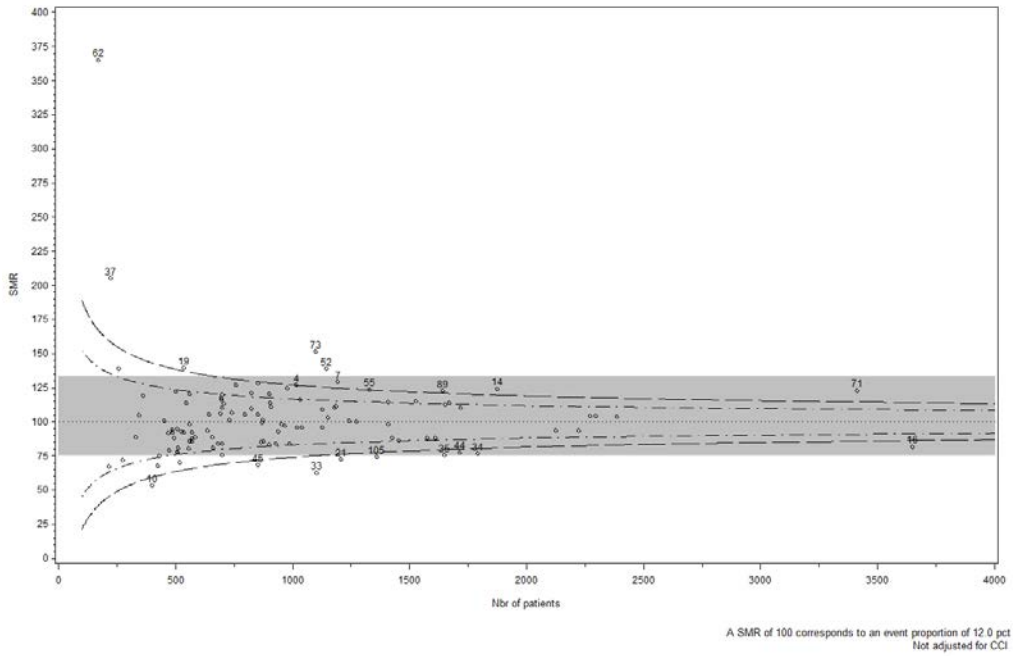
A SMR of 100 corresponds to an event proportion of 12.0 pct
Initial model



A SMR of 100 corresponds to an event proportion of 13.0 pct
Losses of less than 8 days excluded


SMR
Nbr of patients
A SMR of 100 corresponds to an event proportion of 8.1 pct
Patients aged 80y+ excluded


SMR
Nbr of patients
A SMR of 100 corresponds to an event proportion of 12.0 pct
Not adjusted for intensity of care



A SMR of 100 corresponds to an event proportion of 12.0 pct
Not adjusted for CCI