Variation in the rates of adverse events between hospitals and hospital departments

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Abstract

Objective. The objective of this study was to analyze the variation in the rates of adverse events (AEs), and preventable AEs, between hospitals and hospital departments in order to investigate the room for improvement in reducing AEs at both levels. In addition, we explored the extent to which patient, department and hospital characteristics explain differences in the rates of AEs.


Setting. Twenty-one Dutch hospitals.


Main outcome measures. Variation in AEs, and preventable AEs, between hospitals and hospital departments and the explanatory factors of the variation.

Results. The rates of AEs varied between hospitals ($P = 0.05$) and hospital departments ($P < 0.05$). The rates of preventable AEs only varied significantly between hospital departments. The clustering of preventable AEs in hospital departments was more than twice that found in hospitals (ICC 9.5 versus 3.5%). The type of hospital explained 35% of the inter-hospital variance in AEs. Patient and department characteristics explained 23% of the inter-department variance in preventable AEs.

Conclusions. In addition to interventions to improve the overall patient safety within a hospital, interventions tailored for specific departments are necessary to reduce their patient safety risks. Monitoring and comparing the performance of hospitals should not be limited to the hospital level, but should be extended to the individual department since there can be significant differences in the rates of preventable AEs between different departments within the same hospital.

Keywords: adverse events, hospital, safety, record review, risk management

Introduction

Patient record review studies have shown that a substantial number of patients in acute care hospitals experience adverse events (AEs) and that part of the AEs contributed to the patient’s death. Approximately half of the AEs were judged to be preventable [1–12]. Based on these findings, patient safety programs have been initiated to reduce the amount of AEs.

There is a growing interest in measuring the variation in the quality of health care between healthcare institutions. Comparative measures of mortality and morbidity are used by healthcare professionals to improve care, by patients to select their caregiver, by insurers to contract doctors and hospitals and by hospital managers and policy makers to monitor the quality of care [13]. Hospital care is organized at different levels and it is argued that the incidence rates of AEs differ more between hospital departments than between hospitals. Hospital departments are specialist units, such as cardiology, intensive care and neurology, and vary widely in the services they offer. Moreover, the study of Smits et al. [14] showed that the patient safety culture among hospital employees varies more between hospital departments than
between hospitals. There is limited information about the extent of variation in the incidence rate of AEs between hospitals and between hospital departments. This limits insight into the room for improvement at the hospital, and hospital department, levels.

Between August 2005 and October 2006, a patient record review study was carried out to assess the national incidence of AEs in Dutch hospitals. The study showed that in 5.7% [95% confidence interval (CI): 5.1–6.4] of the hospital admissions one or more AEs were found and that in 2.3% (95% CI: 1.9–2.7) one or more preventable AEs were detected [15].

In this article, we used multilevel analysis to examine the variation in the overall rates of AEs, and rates of preventable AEs, between hospitals and between hospital departments. We also examined the influence of patient mix, department characteristics and the type of hospital on the variation in the rates of AEs and preventable AEs. The composition of patients differs between hospitals and hospital departments. For example, complex patients are often referred to university hospitals and patients admitted to surgical departments are at higher risk of suffering from AEs [15]. To attribute the variation in the rates of AEs to hospitals and hospital departments, sufficient correction for patient mix and structural factors, such as hospital type and type of department, is required. The remaining variance after correction gives an indication of the room for improvement at both levels.

The research questions of this study are given below.

(i) To what extent do the rates of AEs, and the rates of preventable AEs, vary between hospitals and between hospital departments?

(ii) To what extent is the variation in AEs, and preventable AEs, between hospitals, and between hospital departments, a result of differences in the composition of the patient population, type of department and hospital type?

**Methods**

**Study design and setting**

A retrospective patient record review study was performed in a stratified random sample of 21 Dutch hospitals: 4 university, 6 tertiary teaching and 11 general hospitals. The level of care given in tertiary teaching hospitals lies between that of a university hospital and that of a general hospital. Generally, university hospitals and to some extent tertiary teaching hospitals treat more complex patients with complex care. Admissions of university hospitals were oversampled to facilitate the comparison between the different types of hospital. To increase the efficiency in identifying AEs, admissions of patients who died during their hospital admission were oversampled. All figures in this article were corrected for the oversampling of admissions to university hospitals and deceased hospital patients. After correction, the figures were representative for the Dutch population of hospitalized patients [15, 16].

From each hospital, we selected at random 200 admissions (>24 h stay) of discharged patients and 200 admissions of patients who died during their hospital admission. We selected admissions from 2004. Admissions with a diagnosis most related to obstetrics, or psychiatry and admissions of children younger than 1-year old were excluded. Of the initial 8415 sampled admissions, 383 records were unavailable or were inadequate. In addition, 106 records were excluded during the review process (Fig. 1 for a flow chart of the reviewed patient records and reasons of exclusion). Forty-four hospital admissions could not be matched to the national hospital administration database. Since the admission department is only a proxy of the department responsible for patient care during the admission, all AEs that were attributable to a hospital department other than the admission department were excluded from the analysis (n = 130). Finally, 639 records were not involved in the analyses, because a report mark for the quality of record keeping, as
judged by the reviewers, was lacking. In total, 7113 admissions from 300 hospital departments were included in this study (Fig. 1).

Structured review of patient records

The patient records of the sampled admissions were reviewed by a team of 66 trained nurses and 55 trained physicians during a structured record review process. In the first stage, a nurse screened the patient records with 18 screening criteria indicating potential AEs [16]. In addition, patient and admission characteristics were recorded, such as age, sex, urgency of admission and admission department.

In the second stage of the review process, two physicians used a structured form to independently review if the patient records were positive for one or more screening criteria. They assessed the presence and the preventability of AEs. An AE was defined as an unintended injury among hospitalized patients that resulted in disability, death or prolonged hospital stay and was caused by healthcare management rather than the patient's underlying disease process [15]. A ‘preventable’ AE is an AE resulting from an error in management due to failure to follow accepted practice at an individual or system level. Accepted practice was taken to be ‘the current level of expected performance for the average practitioner or system that manages the condition in question’ [16]. Because patients can shift from one department to another during their hospital admission, the physician reviewers recorded which department, e.g. surgery, cardiology, neurology, was responsible for the occurrence of the AE. Finally, the nurse and physician reviewers gave a report mark, from 1 ‘extremely poor’ to 10 ‘extremely good’, for the quality of the record keeping. The review process for determining AEs is based on previous AE studies in other countries and have been described in more detail elsewhere [15, 16].

Additional data were obtained from the national hospital administration database, notably the Charlson index for co-morbidity and diagnosis coded according to the International Statistical Classification of Diseases, 9th revision (ICD-9). The Charlson index is a weighted estimate for co-morbidity and takes into account both the number and seriousness of co-morbid diseases [17]. The ICD-9 diagnoses were classified according to the Clinical Classifications Software (CCS) into homogeneous diagnostic groups [18]. The major CCS diagnostic classification was used instead of ICD-9 diagnoses, because they showed a stronger association with AEs than the ICD-9 main categories.

The study protocol was approved by the Amsterdam VU University Medical Centre Ethics Board.

Statistical analysis

Descriptive statistics were calculated for the characteristics of the study population using weights for the oversampling of deceased patients and patients admitted to university hospitals in SPSS 14.0 [15].

The data in this study were hierarchical. At the first level, 7113 patient admissions were nested within 300 hospital departments, which were the second level. These were, in turn, nested within 21 hospitals, the third level. Thus, the observations were not independent, which violates a major assumption of traditional regression analysis. Multilevel models are used to analyze hierarchically structured data [19, 20]. We used multilevel logistic regression (MLwiN version 2.02) to analyze the variance in the dichotomous outcome variables, AEs and preventable AEs, coded as 'present' or 'not present'.

To ensure that the differences in the rates of AEs found in the multilevel analysis were attributable to differences between hospitals and between hospital departments and not to differences in the composition of patient groups, we corrected for differences in patient characteristics. We presumed that patient characteristics do not completely account for compositional differences. It is also necessary to correct for contextual factors, notably the type of admission department and type of hospital, because patients admitted to a surgical department or to university hospitals have an increased risk of AEs due to unobserved patient characteristics [15]. Also a correction for the quality of the record keeping is needed, because the diligence with which information is recorded may influence the visibility of AEs.

Model 1 was a null model, in which the inter-hospital and the inter-hospital department variations in AEs were analyzed without considering covariates. In Model 2, the patient characteristics, age, sex, urgency of admission, length of stay, diagnostic groups and co-morbidity were added. Next, the type of department whether surgical or non-surgical and the report mark for the quality of the record keeping were added (Model 3). Finally, the type of hospital was added: university, tertiary teaching or general hospital (Model 4). Using this strategy, we were able to separate variation between hospitals and between hospital departments and to analyze, at each level, how much variability can be explained by patient mix, department type and hospital type.

All variables included in the models were centered to reference values for all Dutch hospital admissions, and the variances of the models were tested for statistical significance using a one-sided Wald test. Intraclass correlations (ICCs), defined as the higher level variance as a percentage of the total variance, were calculated. A high ICC at the hospital level means that there is more homogeneity within hospitals, meaning a low variation in the way patients are treated in a hospital, but high variation between hospitals [19, 20]. Within logistic models, the variance at the lowest level, in this study the patient, is approximated by \( \pi^2/3 \) to calculate the total variance [19]. In addition, median odds ratios (MORs) were calculated to quantify the differences in the rates of AEs between hospitals and hospital departments (MOR for hospital variation = \( \exp(\sqrt{2 \times \text{hospital-level variance}} \times 0.6745) \)). MOR = 1 is found when there is no variation between hospitals or between hospital departments. It does not make a difference whether a patient is treated in one hospital or another as far as their risk of an AE is concerned. A larger MOR means that patients are better off in some hospitals than in others in terms of their risk of an AE [19, 21].
Finally, Model 4 was used to assess the association between the covariates and the occurrence of AEs by calculating ORs with 95% CIs.

Results

Study sample

In this study, 7113 admissions from 300 hospital departments in 21 hospitals were analyzed. The patient, admission and hospital characteristics of both the study sample and the Dutch population of hospital patients are shown in Table 1.

Variation in rates of AEs

Multilevel logistic regression models for all AEs, and preventable AEs, are shown in Table 2. In all models for all AEs, the intercept variation for the hospital level and the hospital department level was statistically significant \((P < 0.05)\), implying a significant variation in the rates of AEs between hospitals and between hospital departments, with the exception of hospital-level variance in Model 4 \((P = 0.05)\). Compared with Model 1, the intercept-only model, the patient mix and the department type did not reduce the variance in AEs between hospitals. The variance in AEs at the hospital level only reduced after adjustment for hospital type (35%). The variance in AEs at the hospital department level reduced by 16% after adjustment for patient characteristics and 35% after adjustment for patient and department characteristics. Additional correction for hospital type did not reduce the variance in AEs between hospital departments.

After correcting for all covariates, Model 4, the clustering of AEs in hospital departments was almost two times higher than in hospitals, ICC 7.1 versus ICC 3.6%. This means that

<table>
<thead>
<tr>
<th></th>
<th>Study sample</th>
<th>Dutch population of hospital admissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of hospitals</td>
<td>21</td>
<td>101</td>
</tr>
<tr>
<td>Number of patient admissions</td>
<td>7113</td>
<td>1,343,234</td>
</tr>
<tr>
<td>Number of patients admitted to a university hospital (% of total admissions)</td>
<td>1198 (16.8)</td>
<td>781,611 (13.4)</td>
</tr>
<tr>
<td>Number of patients who died during admission (% of total admissions)</td>
<td>3597 (50.6)</td>
<td>42,329 (3.2)</td>
</tr>
<tr>
<td>Mean age (SD; years)</td>
<td>57.9 (21.3)</td>
<td>55.9 (21.7)</td>
</tr>
<tr>
<td>Sex (% male)</td>
<td>48.8</td>
<td>49.7</td>
</tr>
<tr>
<td>Mean length of stay in days (SD/median)</td>
<td>8.5 (10.5/5.0)</td>
<td>7.3 (10.4/4.0)</td>
</tr>
<tr>
<td>Urgent admissions (%)</td>
<td>54.9</td>
<td>46.6</td>
</tr>
<tr>
<td>Admission department (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgery</td>
<td>23.9</td>
<td>23.8</td>
</tr>
<tr>
<td>Cardiology</td>
<td>13.1</td>
<td>16.1</td>
</tr>
<tr>
<td>Internal medicine</td>
<td>15.9</td>
<td>16.2</td>
</tr>
<tr>
<td>Orthopedics</td>
<td>10.7</td>
<td>8.7</td>
</tr>
<tr>
<td>Neurology</td>
<td>7.5</td>
<td>6.3</td>
</tr>
<tr>
<td>Pulmonary disease</td>
<td>7.2</td>
<td>6.4</td>
</tr>
<tr>
<td>Ear, nose and throat</td>
<td>4.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Urology</td>
<td>4.3</td>
<td>5.0</td>
</tr>
<tr>
<td>Other</td>
<td>13.4</td>
<td>13.0</td>
</tr>
<tr>
<td>Mean Charlson index for co-morbidity (% with a score ≥1)</td>
<td>0.10 (7.9)</td>
<td>0.10 (7.9)</td>
</tr>
<tr>
<td>Major CCS diagnoses (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Septicemia</td>
<td>7.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Coma, shock</td>
<td>12.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Diseases of the heart (AMI, VF, valve)</td>
<td>2.6</td>
<td>6.4</td>
</tr>
<tr>
<td>Acute cerebrovascular disease</td>
<td>5.9</td>
<td>1.2</td>
</tr>
<tr>
<td>Diseases of arteries, arterioles and capillaries</td>
<td>5.9</td>
<td>1.7</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Diseases of the digestive system</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Renal failure, urogenital infection</td>
<td>55.9</td>
<td>55.9</td>
</tr>
</tbody>
</table>

*aSource: national hospital administration database (www.prismant.nl). bWeighted for the oversampling of deceased patients and of patients admitted to a university hospital.*
there is more variation in AEs between hospital departments than between hospitals, implying that hospitals with a low rate of AEs may have departments with a high rate of AEs. The rate of AEs varied from 4.2 to 15.6% between hospitals and from 3.2 to 19.7% between hospital departments, which could not be explained by the covariates used. The MOR for AEs was 1.41 for hospitals and 1.63 for hospital departments.

Variation in rates of preventable AEs

In all models for preventable AEs, the intercept variation for the hospital level was not significant, but the intercept variation for the hospital department level was statistically significant, implying significant variation in the rates of preventable AEs between hospital departments. The variance at the level of the hospital department reduced by 23% after adjustment for patient and department characteristics. Additional adjustment for hospital type did not affect the variance at the department level.

Determinants of all AEs and of preventable AEs

Table 3 shows which patient groups have an increased risk of suffering from AEs and from preventable AEs. Patients with a surgical admission, more co-morbidity, higher age, longer length of hospital stay, elective admission or complication of surgical or medical procedures had a higher risk of suffering from AEs and from preventable AEs during a hospital admission. A lower report mark for the quality of record keeping was associated with an increased risk of AEs.
Discussion

General findings

The rates of AEs varied significantly between hospitals and between hospital departments. The rate of AEs that were judged to be preventable varied only significantly between hospital departments. Moreover, the clustering of preventable AEs in hospital departments was more than twice that found in hospitals. This implies that there is more room for improvement in patient safety at the hospital department level than at the hospital level. In addition to hospital-wide interventions to improve the overall patient safety, specific attention is needed to decrease the variance in patient safety between hospital departments. The MOR gives an indication of the risk of an AE due to differences between hospitals or between hospital departments. In this study, the MOR for preventable AEs was 1.42 for hospitals and 1.55 for hospital departments, meaning that the differences between hospitals and hospital departments form a higher risk of preventable AEs than co-morbidity (OR = 1.38).

In this study, the inter-hospital variance in the rates of AEs was mainly explained by hospital type. Patient mix and department type did not further reduce the inter-hospital variance in AEs, contrary to the general perception that differences in the rates of AEs between hospitals are strongly related to differences in patient mix. The fact that inter-hospital variance actually increased after including patient mix and department type indicates that these variables masked some of the inter-hospital variance. The inter-department variance in both the rates of AEs and the rates of preventable AEs was mainly explained by differences in the patient mix and department type.

This study gives an insight into patient groups with a higher risk of preventable AEs. Increasing age and more co-morbidity were associated with an increased risk of preventable AEs. Thus, patient safety interventions should be focused on vulnerable elderly patients and patients with co-morbidity. Also, longer hospital stays were associated with an increased risk of preventable AEs, but it is not clear whether length of stay is a cause or a result of the occurrence of preventable AEs. In addition, patients who undergo a surgical procedure are at a higher risk. The association between elective admission and an increased risk of preventable AEs seems counterintuitive. Perhaps, risks may be underestimated, specifically in routine surgery. The quality of record keeping seems to be a predictor of the outcome of health care: a lower report mark was associated with higher rates of AEs. Better documentation of patient information may prevent adverse outcomes.

Comparison with previous record review studies

A few previous record review studies have measured the association between the organizational factors, such as hospital type, and the rates of AEs [22, 23]. The results of these studies are conflicting and the researchers did not take into account...
account the hierarchical structure of the data, which is mostly ignored in retrospective record review studies on AEs. Restricting attention to a single organization level fails to take into consideration the nested structure of healthcare organizations and the consequences of such nesting for measuring quality [24]. Various studies showed that ignoring these levels within healthcare organizations, valuable findings, like differences in patient safety culture and adverse patient outcomes between hospital departments, will remain undisclosed [14, 25, 26].

Methodological considerations

This study has some limitations. The inter-rater agreement for the judgment of AEs was fair for the assessment of AEs ($\kappa = 0.25$) and their preventability ($\kappa = 0.40$) [15, 16, 27, 28]. Besides, the exploratory analysis of organizational factors in this study was restricted to adding the type of admission department (surgical and non-surgical), quality of the record keeping and hospital type (university, tertiary teaching and general). We assume that the effects of these variables partly reflect unobserved patient characteristics, emphasizing how difficult it is to ensure an optimal correction for patient mix. Including the report mark for the quality of the record keeping in the models may have led to overcorrection since poor quality of record keeping may be both a cause and a consequence of poor quality of care. This also concerns the inclusion of the length of stay in the models.

Implications for practice and future research

The findings of our study have implications for improving patient safety in hospitals and future research. This study shows that the rates of preventable AEs only varied significantly between hospital departments, implying that there is more room for improvement in patient safety at the hospital department level than at the hospital level. In addition to patient safety interventions to improve the overall patient safety within a hospital, interventions tailored for individual hospital departments are necessary to reduce their patient safety risks. To formulate tailored interventions, a profound understanding of the nature and underlying causes of AEs of a department is necessary, since such understanding will facilitate implementation of effective interventions to reduce the variation.

Hospital comparators, including caregivers, patients, managers, policy-makers and insurers, should be aware of unsafe hospital departments when measuring, monitoring and comparing the performance of hospitals and the effect of safety programs. Hospitals with an overall low rate of AEs may have departments with the high rates of AEs. Measurement at the department level is also more appropriate to formulate interventions and implementation strategies tailored to the problems of specific hospital departments. Hospital managers should identify high-risk departments and safety programs should focus on patient groups or clinical areas with a higher risk of preventable AEs, such as elderly patients and patients that undergo surgical procedures.

Unmeasured organizational factors in this study, such as safety culture, level of experience and skills of medical and nursing personnel, the number and variety of the total staffing, including support personnel, the availability and quality of facilities, and differences in the function of the hospitals’ quality and safety management systems may explain the remaining unexplained variance and should be explored in future studies.

In addition, future studies on the variation of AEs could be extended to include a ‘physician level’ or ‘unit level’. Physicians or units, such as operation teams, are nested within departments and have their own culture and organization of healthcare delivery. The variation associated with this unmeasured level was scattered over the department and patient levels in this study. An extra level in future studies should, however, be accompanied by the inclusion of more cases.

This study looked at the variance in AEs between all the hospital departments included in our study. It would be interesting to explore in future studies the variance in AEs between specific specialties, such as cardio-thoracic surgery and intensive care. The number of cases in this study was too small to analyze the differences in AEs between specific specialties.

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