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# The relationship between inpatient cardiac surgery mortality and nurse numbers and educational level: Analysis of administrative data

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## Abstract

**Background—**In most multicenter studies that examine the relationship between nurse staffing and patient safety, nurse-staffing levels are measured per hospital. This can obscure relationships between staffing and outcomes at the unit level and lead to invalid inferences.

**Objective—**In the present study, we examined the association between nurse-staffing levels in nursing units that treat postoperative cardiac surgery patients and the in-hospital mortality of these patients.

**Design-setting-participants—**We illustrated our approach by using administrative databases (Year 2003) representing all Belgian cardiac centers ($n = 28$), which included data from 58 intensive care and 75 general nursing units and 9054 patients.

**Methods—**We used multilevel logistic regression models and controlled for differences in patient characteristics, nursing care intensity, and cardiac procedural volume.

**Results—**Increased nurse staffing in postoperative general nursing units was significantly associated with decreased mortality. Nurse staffing in postoperative intensive care units was not significantly associated with in-hospital mortality possibly due to lack of variation in ICU staffing across hospitals.

**Conclusion—**This study, together with the international body of evidence, suggests that nurse staffing is one of several variables influencing patient safety. These findings further suggest the need to study the impact of nurse-staffing levels on in-hospital mortality using nursing-unit-level specific data.



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**Keywords**

Nurse staffing; Patient safety; In-hospital mortality; Cardiac surgery

## What is already known about this topic?

- A great number of studies showed an association between nurse-staffing levels and patient safety.
- Most large multicenter studies that investigate the relationship between nurse staffing and patient safety aggregate nurse-staffing levels per hospital.
- In Belgium minimum nurse-staffing ratios are integrated in the hospital financing system, resulting in limited between hospital variability in nurse-staffing levels. A nationwide study about the relationship between nurse staffing and patient safety, measuring nurse staffing at the hospital level, did not find any significant associations.

## What this paper adds

- This study, conducted in Belgium, illustrates that nurse-staffing levels of postoperative general cardiac nursing units are associated with in-hospital mortality among cardiac surgery patients.
- The results of this study show that under conditions of homogenous staffing at the hospital level, significant results have not been found at the hospital level, whereas they have at the unit level. The results draw attention to the importance of studying the link between nurse staffing and patient safety using nursing unit level data of those nursing units where the included patients stayed during their hospitalization.

## 1. Background

The role of nurses' practice environment in acute care hospitals on patient safety has gained increased attention during the last decade. Most studies have focused on the impact of nurse-to-patient ratios on patient safety. Most, if not all, large multicenter studies have investigated this relationship by aggregating nurse-staffing data at the hospital level, including nurse-staffing data from nursing units where the patient group that is studied does not stay (Aiken et al., 2002; Needleman et al., 2002; Rafferty et al., 2007). Using the hospital level as the unit of analysis implies that data about nurse staffing from individual nurses or nursing units are aggregated at the hospital level (i.e., one score per hospital). This requires fairly homogenous nurse-staffing levels across the units within hospitals, an assumption that these studies rarely address. The majority of studies conducted at the hospital level report a statistically significant association between nurse-staffing levels and patient safety measures (e.g., adverse events) (Aiken et al., 2002; Needleman et al., 2002; Rafferty et al., 2007; Kane et al., 2007) however, each study may differ from another regarding which patient outcome is significant (Unruh, 2008). A recent Belgian study failed to identify any associations between nurse-staffing levels (measured at the hospital level), in-hospital mortality, and nine adverse events (Van den Heede et al., 2008a) in patient populations comparable to those examined in earlier research conducted in the U.S.A. (Aiken et al., 2002) and the U.K. (Rafferty et al., 2007). One explanation that was proposed was that due to the national legislation, nurse-staffing levels in Belgian hospitals varied very little (Van den Heede et al., 2008a). After all, a system of minimum baseline nurse-staffing ratios is integrated into the Belgian hospital financing system. Hospitals receive a fixed minimum budget for nursing staff per discipline (e.g., 12 full time equivalent nurses per 30 general surgical beds). In addition, a corrective system exists to allocate hospitals that have a high intensity of nursing care, a higher nurse-staffing budget than those with a lower intensity of nursing care. Therefore, when nurse-staffing varies, it is most likely due to differences in the intensity of nursing care and is thus justified. Van den Heede et al. (2008b) studied the variability in the number of nursing staff in all Belgian acute hospitals (including data from all adult general medicine/surgical and intensive care nursing units), using national data collected during the 20 B-NMDS observation days of the year 2003. The authors found that 87% of the variability could be attributed to the nursing unit level, 12% to the observation day level and 1% to the hospital level. Even after correcting for type of nursing unit (i.e. general versus intensive care) and the intensity of nursing care, the greater part (54%) of unexplained variability in the number of nursing staff was attributed to the nursing unit level (Van den Heede et al., 2008b). This higher observed variability of nurse-staffing levels within Belgian hospitals (Van den Heede et al., 2008b) indicates that hospital administrators allocate the overall nurse-staffing budget, which is more or less the same for all hospitals, to different nursing units unevenly. Thus, staffing–outcomes relationships may be masked in hospital-level analyses.

However, little is known about how nurse-staffing levels in nursing units affect patient safety within those units. To date, despite some exceptions (Blegen and Vaughn, 1998; Mark et al., 2007; McGillis-Hall et al., 2003) the use of nursing unit level data is limited to small-scale settings (e.g., intensive care units) obtained through primary data collection (Amaravadi et al., 2000; Dang et al., 2002). Studies involving small-scale settings fail to obtain consistent results perhaps because they are underpowered (Blegen, 2006).

The current study represents one of the first attempts to use administrative databases to examine the relationship between nurse-staffing levels and patient safety in a multicenter setting in which staffing data were used from the nursing units where the patients under study were actually treated. Nurse-staffing levels of two specialized nursing units—postoperative cardiac intensive care units and postoperative cardiac general nursing units—were linked to in-hospital mortality during the postoperative care of cardiac surgery patients. We chose to study the cardiac surgery population because these patients are treated in a limited number of specific nursing units, thus facilitating in-depth analysis. At the same time, the cardiac surgery population is a high risk and high volume population with a longstanding tradition in public reporting and healthcare outcome measurement (Normand and Shahian, 2007).

One of the mechanisms believed to be operating in relationships between nurse staffing and patient safety relates to the difficulties in carrying out adequate patient surveillance when nursing units are understaffed (Clarke and Donaldson, 2008), resulting in an increased incidence of adverse events. Cardiac surgery patients, in particular, are hypothesized to be especially vulnerable to differences in nurse-staffing levels, since these patients require a great deal of nursing surveillance during the postoperative period (Whitman et al., 2002). This hypothesis drives the main objective of the present study: to examine the association between nurse-staffing levels (number and educational level) of nursing units that treat postoperative cardiac surgery patients and the in-hospital mortality of these patients.

## 2. Methods

### 2.1. Data sources

In this study, we analyzed two administrative databases—the Belgian Nursing Minimum Dataset (B-NMDS) and the Belgian Hospital Discharge Dataset (B-HDDS)—for the year 2003 (i.e. the most recent year made available by the Ministry of Public Health for which the B-NMDS could be linked to the B-HDDS). Both databases are mainly used for hospital financing purposes. Contribution of data to the B-NMDS and B-HDDS has been compulsory for all acute hospitals since 1988 and 1990, respectively. The content of the B-HDDS is comparable with that of international hospital discharge data (demographic characteristics; length of stay; diagnoses based on International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM); and procedures). The B-HDDS also keeps track of the sequence and time (expressed in days) a patient stays in different nursing units. Since 2000, B-HDDS data and B-NMDS data became linkable through common nursing unit and patient identifiers. The linking of these two datasets enabled us to study the nurse staffing and patient safety relationship on a more detailed level than what is generally possible when using administrative databases. The B-NMDS contains individual nursing-unit data on staffing patterns and the nature of nursing care provided by all Belgian acute care hospitals. The Ministry of Public Health randomly samples data from 5 of the first 15 days of March, June, September, and December, and instructs hospitals to collect and transfer the data to the national database. For every patient admitted to 1-day hospitalization clinics or inpatient hospitalization nursing units, a list of nursing interventions (i.e., 23 items) is scored. In addition, for every nursing unit (where those patients are treated), the number of nurses involved in direct patient care and the hours they worked are recorded. Every nursing unit is classified according to the type of nursing unit (e.g., intensive care, surgical, internal medicine, geriatric). Details regarding the data collection instrument (nurse-staffing variables, nursing interventions, and response categories) and auditing procedures are described by Sermeus et al. (2008).

## 2.2. Study sample

The study sample was restricted to all patients, aged between 20 and 85 years, that were electively admitted to a Belgian acute hospital for a coronary artery bypass graft (CABG) or heart valve procedure. We chose this study population since the patients undergoing these two types of cardiac procedures follow a highly similar and standardized patient trajectory. We considered patients as having a CABG or heart valve procedure if they were assigned to one of the following categories from All patients refined diagnosis-related-group (APR-DRG), version 15.0: 162 (heart valve procedures with heart catheterization); 163 (heart valve procedures without heart catheterization); 165 (CABG with heart catheterization); or 166 (CABG without heart catheterization). Only patients that underwent a cardiac surgery procedure within the first 15 days of their hospitalization were retained. The selected cardiac procedures involved specialized care that is delivered in 29 of the 115 Belgian acute care facilities. One hospital was dropped from the analysis because the nursing unit identifiers did not allow a link between the B-NMDS and the B-HDDS. Since we were interested in how nurse-staffing levels affected patient mortality during the postoperative period, patients who died before or during their procedures were removed from our analyses (0.4%). Also excluded from analyses patients were patients whose records did not permit linkage to a specific nursing unit postoperatively (2.5%). The final sample comprised 9054 patients.

## 2.3. Study variables

The choice of the study variables was based on a list of key variables for nurse staffing and patient safety research constructed by an international expert panel (Van den Heede et al., 2007) in combination with the availability of these variables in the current Belgian administrative databases. The outcome measure of interest in this study was in-hospital mortality. In-hospital mortality is the only outcome measure in the B-HDDS for which a time stamp is available. Moreover, the nursing unit where a patient died can be identified. This information was necessary to exclude patients that died during operation and to include only patients that received care during the postoperative period.

To control for differences in relative risks on mortality among hospitals, a patient’s age, gender, type of procedure (i.e., APR-DRG), and risk of mortality were included in the analysis. Per Diagnostic Related Group patients are assigned to one out of the four risk-of-mortality categories (minor, moderate, major, extreme) based on their second-ary diagnoses (Averill et al., 2003). In the B-HDDS information on whether secondary diagnoses were present on admission is not coded. This deficit makes it impossible to directly determine whether a patient had already received a secondary diagnosis prior to the time of admission (i.e., comorbidity) or whether the patient had received a secondary diagnosis during the course of his hospital stay (i.e., adverse event). We aim to correct only for comorbidities, not for complications since they can be a result of differences in the explanatory variables. Therefore, using the 3M grouper software, we re-calculated the risk-of-mortality categories without the secondary diagnoses, which are used in the numerators of patient safety algorithms (Department of Health and Human Services, 2007) since these secondary diagnoses are more likely to show a complication than a comorbidity.

The explanatory variables of interest in this study were the number of nursing staff and educational level of nursing staff. The number of nursing staff, measured by the nursing hours per patient day (NHPPD), was calculated for each nursing unit by dividing the total hours worked by registered nurses during a 24-h period by the patient census for that day. The educational level was measured by calculating the proportion of registered nurses with a Bachelor's degree in each nursing unit. Nurse-staffing levels are influenced by the intensity of nursing care. One nursing unit may be adequately staffed for its intensity of nursing care at a particular NHPPD, while another may be short staffed (Needleman et al., 2007). Therefore, adjustments are necessary in order to compare NHPPDs across nursing units or hospitals. In our study, we obtained a measure of the intensity of nursing care from the 23 B-NMDS items. This measure of the intensity of nursing care was recently validated by Sermeus et al. (2008). This intensity of nursing care has shown to correlate poorly with pathology information (i.e. APR-DRG) (Sermeus et al., 2008), as was previously illustrated in international research (Welton and Halloran, 2005).

To control for different hospital characteristics, we retained cardiac procedural volume (i.e., all CABGs and heart valve surgery performed in an institution, including non-elective admissions) in this study. Many studies have found that hospitals that perform relatively more cardiac procedures have better patient outcomes (Marcin et al., 2008).

### 2.4. Data structure and statistical analysis

Data were structured hierarchically into three levels: hospitals (procedural volume); nursing units (staffing variables, intensity of nursing care, type of nursing); and patients (patient characteristics, in-hospital mortality). In addition, some patients were cared for by different nursing units during their stay and thus can belong to more than one nursing unit. We identified that, in 72.2% of the patients, an elective hospitalization for cardiac surgery included four episodes of care: pre-operative care in a general nursing unit, operative care in an operation theatre, postoperative care in an intensive care nursing unit, and postoperative care in a general nursing unit. However, more than 20 other combinations of nursing units were observed in the data. Since we were interested in how nurse-staffing policy affects the immediate postoperative period, we selected only nurse-staffing variables from the first postoperative intensive care unit and the first postoperative general nursing unit. This resulted in the identification of 58 intensive care nursing units and 75 general nursing units, that treated cardiac patients during the immediate postoperative period. The number of intensive care nursing units and general nursing units where patients of the study sample stayed ranges from 1 to 5 per hospital for both nursing unit types. Most patients are (i.e. threshold of minimum 15 patients per nursing unit), however, treated on 1 (22 hospitals); 2 (4 hospitals) or 3 (2 hospitals) intensive care nursing units and 1 (21 hospitals) or 2 (7 hospitals) general nursing units specialized in cardiac care.

Next, to determine which model would be appropriate for our data, we applied a likelihood ratio test using the Restricted Maximum Likelihood Estimation method (indicating limited heterogeneity at the nursing unit level) (Verbeke and Molenberghs, 2000), and found that a two-level model (i.e., hospitals and patients) yielded the best fit to the data. Two types of nursing units were identified for study, and data from these units were aggregated per hospital: postoperative intensive care units and postoperative general units.

We estimated three models to gradually build up the results. In model 1, we controlled for individual patient characteristics (i.e., age, gender, type of surgery, risk of mortality) commonly used in this research field. In model 2, we controlled for the same variables as in model 1 but added the innovative ‘intensity of nursing care’ measure. In model 3, we controlled for the same variables as model 2 and a risk-adjuster which is specific for the cardiac surgery patient population (i.e. cardiac surgery procedural volume). The *c*-statistics for risk-adjusters were 0.92 for model 1 and 0.93 for models 2 and 3. We used a multilevel logistic regression model that assumed that the data had two levels (level 1: patient; level 2: hospital). In each model, we entered four explanatory variables (NHPPD of postoperative intensive care units, proportion of RNs with at least a Bachelor’s degree in postoperative intensive care units, NHPPD of postoperative general nursing units, proportion of RNs with at least a Bachelor’s degree in postoperative general nursing units). Non-significant explanatory variables (Proportion of RNs with at least a Bachelor’s and NHPPD on postoperative intensive care units) were reduced stepwise from the final analysis.

To portray the clinical importance of the model results a simulation study was carried out using the final model. Since we are interested in assessing the impact of nurse staffing, it was considered what would happen had all the nursing units increased their staffing to the 75th percentile (keeping the current values for nurse staffing for the nursing units above this threshold). These new nurse-staffing values are then used in predicting in-hospital mortality. That is we predicted the response (in-hospital mortality) after “improving” the nurse-staffing regime (for the significant explanatory variables). These responses were added over all the patients and over all the hospitals to get a value for the overall mortality. The 75th percentile as a reference level was chosen based on earlier research (Needleman et al., 2006).

Descriptive analysis and data manipulation was conducted using SAS v9.1 (SAS Institute, 2001). The multilevel analysis was done using R package lme4 (R Development Core Team, 2008).

## 3. Results

### 3.1. Descriptive results

Table 1 provides summary statistics for the variables in our study. The median cardiac procedure volume in Belgian hospitals was 316 (P25 = 215; P75 = 575). In 2003, the median intensive care units were staffed with 11.9 NHPPDs (P25 = 10.3; P75 = 13.1) and 95% of the RNs working on these units have a Bachelor’s degree (IQR = P25 = 89; P75 = 97). The median general nursing units were staffed with 2.91 NHPPDs (P25 = 2.4; P75 = 3.5) and 69% of the RNs working on these units have a Bachelor’s degree (P25 = 61; P75 = 75).

The median length of hospital stay was 11 days. The overall in-hospital mortality was 3.4%. The most commonly performed procedure, CABG without catheterization, had the lowest in-hospital mortality (2.1%). The least frequently performed procedure, heart valve procedure with catheterization, had the highest in-hospital mortality (8.4%). When the total postoperative in-hospital mortality was studied according to the place of death, it appeared that the highest percentage was found in postoperative intensive care units (67.9%), followed by other units after the stay in general postoperative nursing units (21.3%) and postoperative general nursing units (10.8%).

### 3.2. Effect of nurse staffing on in-hospital mortality

Table 2 presents the estimates resulting from the nine multilevel logistic regression models used to study how in-hospital mortality was affected by increases in the NHPPD and by the proportion of RNs with a Bachelor's degree of postoperative intensive care units and postoperative general nursing units. Nurse-staffing variables in postoperative intensive care units had no significant impact on in-hospital mortality. A greater number of NHPPDs in postoperative general nursing units were associated with lower in-hospital mortality in all three models. When controlling for all risk factors (model 3: procedural volume, intensity of nursing care, patient characteristics), we also observed a significant association between the proportion of RNs with a Bachelor's degree on general units and in-hospital mortality.

For the final model, we calculated that 44 patients (95% CI: 43–45) would not have died if all general postoperative cardiac nursing units had 3.5 NHPPDs (75th percentile). This corresponds to 4.9 fewer deaths per 1000 patients admitted for elective cardiac surgery.

## 4. Discussion

Together with the international body of evidence we illustrated that nurse staffing is one of the key factors influencing patient safety. Our results indicate that increasing the nurse-staffing levels of registered nurses (i.e. NHPPD) working in general units, where cardiac surgery patients are treated, was associated with a statistically significant reduction in postoperative in-hospital mortality. At 4.9 patients per 1000 elective cardiac admissions, this reduction is also of clinical importance. However, this estimate of the number of preventable deaths due to increasing the NHPPD should be interpreted with caution. After all, the cross-sectional design of this study does not allow causal inferences. The effect observed on general nursing units could not be confirmed for nurse-staffing levels of the postoperative intensive care nursing units. One possible explanation is that this is due to the smaller variation in NHPPD on intensive care units compared to general units (i.e. increase in NHPPD from P25 to P75 is 46% on general units compared to 27% on intensive care units). Another explanation is that the large observed differences in NHPPD between ICUs and general units (NHPPD are four times higher on ICUs) do not correspond to the differences of a comparable size in the intensity of nursing care. Therefore variations in NHPPD on general units will more rapidly result in significant associations with in-hospital mortality than on the (relatively) well-staffed ICUs. The significant association, observed on postoperative general units, between RNs with a Bachelor's degree and in-hospital mortality (when controlling for differences in patient characteristics, nursing intensity and cardiac procedural volume) should be further explored using data from additional registration years.

These findings are in line with the international literature. Our study findings confirm the evidence for a relationship between nurse-staffing levels and patient safety in a surgical patient population (Kane et al., 2007). Further, it should be noted that the "volume-outcome" relationship was absent in this study. This adds evidence to recent trends in the literature. Marcin et al. (2008) report that although many studies have reported the existence of an association between cardiac surgery hospital volume and mortality, this association has decreased with time.

At the same time, our work differs from previous studies in several ways. The results of our study were not only adjusted for differences in patient and hospital characteristics but also for differences in the intensity of nursing care in the nursing units studied. Furthermore, we found an association between nurse-staffing levels and patient safety for a specific patient population (i.e., cardiac surgery patients) treated in specialized nursing units. Of the previous research that studied how patient outcomes are affected by nurse staffing of nursing units treating specific patient populations, most relied on primary data collection (Blegen, 2006). This is a labor-intensive, costly process that generally results in small-scale studies. In contrast, by linking two administrative databases, we succeeded to study the effect of nurse staffing on in-hospital mortality for all Belgian hospitals that perform cardiac surgery. In doing so, we were able to isolate only nursing units that treated postoperative cardiac surgery patients. In addition, we were also successful in separating in-hospital mortality cases that occurred in postoperative nursing units from those that occurred before or during the operation.

The results of this study demonstrate the importance of studying the impact of nurse-staffing levels on patient safety at the appropriate level. Hospital-level analyses are appropriate when nurse-staffing levels vary more between hospitals than within hospitals. This may be more likely to be the case in countries like the USA. Indeed, in the USA hospital-level studies document an association between nurse staffing and patient outcomes (Aiken et al., 2002; Needleman et al., 2002). Despite these findings, in these countries, the nursing unit is the preferred unit of analysis because conceptually the effect of nurse staffing on patient safety is most direct at the patient-care-unit level (Blegen, 2006). In countries where nurse-staffing levels vary more within hospitals than between hospitals like Belgium, hospital-level analyses can mask possible relationships, as illustrated by the research of Van den Heede et al. (2008a). These authors did not find any statistically significant association between hospital-level staffing levels and adverse events in Belgian hospitals. The results of the current study put those of the study of Van den Heede et al. (2008a) into perspective. Aggregating the staffing levels of all nursing units into one nurse-staffing indicator per hospital obscured the effects of nurse-staffing levels in Belgian hospitals.

Our study has several limitations. First, the accuracy of information extracted from administrative databases might not be as good as clinical data. This would apply to any study that relies on secondary datasets. Indeed, for studying patient safety issues in the cardiac surgery patient population, clinical databases have been shown to be superior to administrative databases (Normand and Shahian, 2007). Generally, administrative databases (e.g., hospital discharge data) are only recommended when clinical data are unavailable. Despite the loss of 2% of the cases due to data quality issues, the use of administrative databases in this study was justified because of the unique possibility of linking nursing data (B-NMDS) with medical data (B-HDDS) at the nursing-unit level.

Secondly, we only assessed the relationship between nurse-staffing levels and in-hospital mortality (instead of the preferred 30-day mortality), and thus did not capture the full impact of low staffing levels. Although prior studies have demonstrated mortality to be a nursing-sensitive measure (Aiken et al., 2002; Kane et al., 2007), mortality is not the only measure for assessing the quality of nursing care. A complex mix of other factors (e.g., severity of illness, surgical performance, random variation) influences the variation in mortality rates. Thus, the international research community recommends researchers to also assess the impact of nurse staffing on other adverse events thought to be sensitive to nursing care (e.g., pressure ulcers, patient falls) and on positive patient outcomes (e.g., functional status) (Van den Heede et al., 2007). However, the current information in the B-HDDS does not allow researchers to isolate events that only occur during the postoperative period.

Thirdly, we aggregated nurse-staffing levels to two types of nursing units—postoperative cardiac intensive care and postoperative cardiac general care nursing units—because some nursing units treated very few cardiac surgery patients resulting in low heterogeneity between the selected nursing units. Our approach, however, is situated between the best approach (measuring precisely how much nursing time each patient receives) and the most commonly used approach (averaging all nursing staff from a hospital, including staff not involved in direct patient care and staff employed that do not treat patients that are studied). Moreover, the carry-over effect of nurse-staffing levels is not captured in the current analyses. Low-staffing on postoperative intensive care units, for instance, can result in mortality on postoperative general units. Nurse-staffing levels are also aggregated per year (based on the 20 days of B-NMDS registration) and thus did not account for the variability in NHPPD over different observation days, which may impact patient safety (Weissman et al., 2007). Fluctuations are thus ignored. Even a nursing unit that had high staffing levels could have had days during the year when it was staffed better or worse compared to other times.

Fourthly, this study focused only on two aspects of the nursing practice environment (i.e., NHPPD and proportion of RNs with at least a Bachelor's degree), leaving many hospital and unit-level organizational factors unmeasured (e.g., nurse–physician relationship, autonomy of nurses, quality of medical care) (Van den Heede et al., 2007). Future research will have to focus on the impact of these factors.

Finally, the generalization of our results is limited, because our current data do not allow the expansion of this study to patient populations treated in a wide range of nursing units. The effect of staffing on the cardiac surgery patient population may differ from the general patient population in Belgian hospitals.

## 5. Conclusion

This study builds on current international evidence supporting the relationship between nurse-staffing levels and patient safety. Moreover, our study illustrates the importance of studying this relationship at the appropriate level (i.e., nursing unit in homogenously organized healthcare systems). This study also generated policy-relevant information. Our results suggest that, in light of the budgetary constraints and the current and projected shortages of nurses, strategic investments in improving nurse-staffing levels should be targeted at the type of nursing unit (e.g., general cardiac nursing units), for which the effects on patient safety are likely to be most beneficial. Given the evidence that staffing levels are associated with patient safety, systems should be developed to monitor this association in a large number of specialties at the nursing-unit level. However, the present study does not demonstrate a causal relationship between nurse-staffing levels and patient safety, nor does it offer insight into the mechanisms behind this relationship. Therefore, the evaluation of natural experiments (e.g., evaluating the impact of changes in nurse-staffing legislation on patient safety) and longitudinal analyses (e.g., changes over time in nurse staffing within a single institution) are needed. Additional research should also focus on many of the unmeasured factors (e.g., the nursing practice environment). In conclusion, the present study adds to the growing body of research establishing an association between more favorable nurse staffing and better patient outcomes. The paper also highlights the potential, and at the same time, the limitations of using current administrative databases to identify potential patient safety problems and associated factors within organizations, particularly when other data are unavailable.

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## Table 1

Summary statistics of patient characteristics, in-hospital mortality, staffing measures, and hospital characteristics.

| | Year 2003 |
|---|---|
| Hospital characteristic | |
| Median cardiac procedural volume per hospital (P25; P75) | 316 (215; 575) |
| Nurse staffing: postoperative intensive care nursing units | |
| Median NHPPD (P25; P75) | 11.86 (10.3; 13.1) |
| Median proportion of RNs with BSN (P25; P75) | 95 (89; 97) |
| Nurse staffing: postoperative general nursing units | |
| Median NHPPD (P25; P75) | 2.91 (2.4; 3.5) |
| Median proportion of RNs with BSN (P25; P75) | 69 (61; 75) |
| Patient characteristics | |
| Percentage males | 70.6% |
| Median age (P25; P75) | 69 years (60; 75) |
| Percentage patients with heart valve procedures with heart catheterization | 5.6% |
| Percentage patients with heart valve procedures without heart catheterization | 26.5% |
| Percentage patients with CABG with heart catheterization | 19.5% |
| Percentage patients with CABG without heart catheterization | 48.4% |
| Median length of stay (P25; P75) | 11 (9; 15) |
| In-hospital mortality | |
| Percentage in-hospital mortality among patients with heart valve procedures with heart catheterization (APR-DRG 162) | 8.4% |
| Percentage in-hospital mortality among patients with heart valve procedures without heart catheterization (APR-DRG 163) | 4.2% |
| Percentage in-hospital mortality among patients with CABG with heart catheterization (APR-DRG 165) | 4.1% |
| Percentage in-hospital mortality among patients with CABG without heart catheterization (APR-DRG 166) | 2.1% |
| Percentage in-hospital mortality among patients in total study sample | 3.4% |

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**Table 2**

Multilevel regression summary for nurse staffing and in-hospital mortality in cardiac surgery patients ($n$ = 9054).

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Intercept | −7.355 (<0.0001) | −6.849 (<0.0001) | −4.198 (<0.0001) |
| Procedural volume | | | 0.0004 (0.2185) |
| Nursing intensity: ICU | | −0.415 (0.5820) | −1.246 (0.0032) |
| Nursing intensity: general nursing units | | 0.576 (0.4434) | 0.424 (0.2824) |
| Male | −0.291 (0.0456) | −0.295 (0.0429) | −0.284 (0.0472) |
| Age | 0.036 (<0.0001) | 0.036 (<0.0001) | 0.037 (<0.0001) |
| APR-DRG 163 | −0.162 (0.5166) | −0.163 (0.5154) | −0.114 (0.6304) |
| APR-DRG 165 | −0.033 (0.8938) | −0.031 (0.8997) | −0.065 (0.7922) |
| APR-DRG 166 | −0.354 (0.1562) | −0.355 (0.1552) | −0.348 (0.1427) |
| ROM 2 | −0.072 (0.9157) | −0.074 (0.9144) | −0.113 (0.8660) |
| ROM 3 | 2.048 (0.0002) | 2.038 (0.0002) | 1.903 (0.0004) |
| ROM 4 | 5.240 (<0.0001) | 5.230 (<0.0001) | 4.974 (<0.0001) |
| NHPPD of general units | −1.227 (0.0448) | −1.342 (0.0475) | −1.395 (<0.0001) |
| Proportion of RNs with BSN on general units | | | −2.164 (0.0012) |

Model 1: adjustment for patient characteristics; model 2: adjustment for patient characteristics and nursing intensity; model 3: adjustment for patient characteristics, nursing intensity, and hospital characteristics; APR-DRG: All-Patient Refined Diagnosis Related Groups; ROM: Risk of Mortality; NHPPD = nursing hours per patient day; Proportion RNs with BSN = proportion of registered nurses with at least a bachelor’s degree; ICU = intensive care unit. The results of NHPPD of ICUs and Proportion of RNs with BSN in ICUs are not shown in the table because these explanatory variables were non-significant.