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ICU nurse-to-patient ratio is associated with complications and resource use after esophagectomy

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Abstract *Objective:* To determine if having a night-time nurse-to-patient ratio (NNPR) of one nurse caring for one or two patients (> 1:2) versus one nurse caring for three or more patients (< 1:2) in the intensive care unit (ICU) is associated with clinical and economic outcomes following esophageal resection. *Design:* State-wide observational cohort study. Hospital discharge data was linked to a prospective survey of ICU organizational characteristics. Multivariate analysis adjusting for case-mix, hospital and surgeon volume was used to determine the association of NNPR with in-hospital mortality, length of stay (LOS), hospital cost and specific postoperative complications. *Setting:* Non-federal acute care hospitals ($n = 35$) in Maryland that performed esophageal resection. *Patients and participants:* Adult patients who had esophageal resection in Maryland, 1994 to 1998 ($n = 366$ patients). *Measurements and results:* Two hundred twenty-five patients at nine hospitals had a NNPR > 1:2; 128 pa-

tients in 23 hospitals had a NNPR < 1:2. No significant association between NNPR and in-hospital mortality was seen. A 39% increase in median in-hospital LOS (4.3 days; 95% CI, (2, 5 days); $p < 0.001$), and a 32% increase in costs (\$4,810; 95% CI, (\$2,094, \$7,952) was associated with a NNPR < 1:2. Pneumonia (OR 2.4; 95% CI (1.2, 4.7); $p = 0.012$), reintubation (OR 2.6; 95% CI(1.4, 4.5); $p = 0.001$), and septicemia (OR 3.6; 95% CI(1.1, 12.5); $p = 0.04$), were specific complications associated with a NNPR < 1:2. *Conclusions:* A nurse caring for more than two ICU patients at night increases the risk of several postoperative pulmonary and infectious complications and was associated with increased resource use in patients undergoing esophageal resection.

Key words Intensive care unit · Administration · Nursing staff · Hospital length of stay · Complications · Cost

Introduction

Much of the morbidity and mortality associated with surgery is a result of postoperative complications, especially in high-risk patients [1, 2, 3]. Because high-risk patients are routinely cared for in the intensive care unit (ICU), quality improvement efforts focusing on ICU organizational characteristics may improve outcomes for

these patients [4, 5, 6]. We have previously shown that abdominal aortic surgery patients who have daily rounds by an ICU physician have a reduced risk of in-hospital mortality, reduced length of stay (LOS) and a decreased risk of postoperative complications [4].

Intensive care nursing can also influence postoperative outcomes for high-risk surgery patients [4, 7]. Previously we have shown a low nurse-to-patient ratio during

the day was associated with increase in ICU length of stay and increased risk of developing postoperative pulmonary complications in patients undergoing abdominal aortic surgery [7]. The objective of our current study is to determine if nurse staffing at night has a similar effect for another high-risk surgical procedure. We hypothesized that differences in nurse staffing at night are related to the development of postoperative complications, in-hospital mortality, LOS and cost for patients undergoing esophageal resection.

Materials and methods

Patient data

Patient data was obtained from non-confidential hospital discharge data available from the Maryland Health Service Cost Review Commission (HSCRC). The database contains information for all 52 non-Federal, acute-care hospitals in Maryland. All adult patients discharged from Maryland hospitals from 1994 to 1998 with a primary procedure code for esophageal resection were included. The primary procedure codes based on the *International Classification of Disease, 9th revision, Clinical Modification* (ICD-9-CM) were as follows: partial esophagectomy, ICD-9-CM code 42.41, total esophagectomy ICD-9-CM code 42.42, and esophagectomy, not otherwise specified, ICD-9-CM code 42.40. For all patients older than 18 years of age, we obtained the following variables from the HSCRC database: age, sex, race, nature of admission (elective, urgent, emergent) [8], operating physician, type of operation (transhiatal, transthoracic, unspecified), vital status at discharge, hospital LOS, ICU days, hospital charges. Using ICD-9-CM codes, up to 14 secondary discharge diagnoses and 14 secondary procedures were identified for each patient, providing information about comorbid disease states as well as postoperative complications. The protocol was approved by the Johns Hopkins Hospital Committee on Clinical Investigation for the use of non-confidential patient data.

Intensive care unit (ICU) organizational data

A survey based on a previously validated questionnaire [9] of ICU organizational characteristics was mailed to the ICU director of the 52 acute-care hospitals in the state of Maryland in 1996. The survey identified 32 characteristics of ICU physician and nurse staffing, as well as other aspects of ICU organization and processes of care. The survey was reviewed independently by five intensive care physicians to ensure content validity [4]. Specific questions related to ICU nurse staffing identified sites with a nurse-to-patient ratio of greater than or equal to 1:2 versus less than 1:2 both during the day and at night. A nurse-to-patient ratio of less than 1:2 means that each nurse cared for three or more patients (< 1:2) and a nurse to patient ratio greater than or equal to 1:2 means that one nurse cared for one or two patients (> 2). Other details of survey development have been previously described [9].

Outcomes

The primary outcome variables were in-hospital mortality, hospital LOS and total hospital cost. Charges were converted to cost using the hospital specific ratio of cost to charges (RCC) averaged from

1994 to 1998. Costs were adjusted for inflation using the consumer price index for health care and are presented in 1998 dollars. In addition to these primary outcomes, two ICU physicians selected ICD-9-CM codes for secondary diagnoses that reflected postoperative complications previously shown to be associated with the primary outcomes and were previously validated by chart review [6]. The complications are as follows: aspiration (ICD-9-CM codes 507 and 9973); pulmonary insufficiency (ICD-9-CM codes 5184, 5185, and 5188); pneumonia (ICD-9-CM codes 480–487); reintubation (ICD-9-CM code 9604); septicemia (ICD-9-CM code 038); postoperative infection (ICD-9-CM codes 9985); cardiac complications (ICD-9-CM code 9971); cardiac arrest (ICD-9-CM code 4257); acute myocardial infarction (ICD-9-CM code 410); acute renal failure (ICD-9-CM code 584); reoperation for bleeding (ICD-9-CM codes 3941, 3949, and 3998); surgical complications after a procedure (ICD-9-CM codes 9981, 9982, 9983).

Statistical analysis

Descriptive analyses of patient and hospital characteristics and primary outcomes at hospitals with a night-time nurse-to-patient ratio (NNPR) > 1:2 versus a NNPR < 1:2 was performed. From unique physician identifiers we were able to determine individual surgeon and hospital volumes for esophageal resection. A Lowess smoothing curve was used to determine the cut-off (“low” versus “high”) for both surgeon volume and hospital volume [10]. The natural cut-offs were 25 cases during the study period for hospital volume and ten cases for surgeon volume. As appropriate, we used the following tests to evaluate for unadjusted associations between nurse staffing and outcomes; chi-square, simple logistic regression, *t*-test, Wilcoxin rank-sum test and simple linear regression. Univariate predictor variables with a *p* less than 0.1 were included in the multivariate analysis. The Spearman-rank correlation was used to test for collinearity of predictor variables; when two variables were collinear the variable with the least variance was used in the multivariate analysis.

We used a multivariate analysis to determine if NNPR < 1:2 was an independent predictor of each of the primary outcome variables. For in-hospital mortality logistic regression was used and for hospital LOS and total hospital cost linear regression was used. These models adjusted for age, sex, nature of admission, type of operation, comorbid disease and hospital and surgeon volume. In order to adjust for comorbid disease states, a Romano-Charlson Comorbidity Index was used [11, 12, 13]. The hospital LOS was log-transformed to achieve a normal distribution. Finally, we repeated the multivariate analysis using a multi-level hierarchical model [14] in order to assess the impact of clustering of outcomes within a hospital. All reported *p* values are two-tailed, and are considered significant if *p* is less than 0.05. STATA 5.0 (Houston, TX) was used to perform the analysis.

Results

Baseline demographics and crude outcomes

A total of 366 adult patients underwent esophageal resection in 35 acute-care hospitals in the state of Maryland between 1994 and 1998. Unit survey data was available for 32 of 35 centers performing esophageal resection, providing information pertinent to the care of 353 of 366 patients (96%). Table 1 reports the patient char-

Table 1 Characteristics of 366 esophageal resection patients with a night-time nurse-to-patient ratio where one nurse cares for one or two patients (> 1:2) versus one nurse caring for three or more patients (< 1:2) in Maryland, 1994–1998 (NNPR night-time nurse-to-patient ratio, SD standard deviation)

Patient characteristics	NNPR < 1:2	NNPR > 1:2
Number of patients(%)	128 (36%)	225 (64%)
Age, mean (SD)	63 (12)	60 (12)
Male (%)	70	79
White race (%)	77	83
Type of operation		
Transthoracic esophagectomy (%)	30	25
Nature of operation		
Elective (%)	77	88
Urgent (%)	9	8
Emergent (%)	12	4
Comorbid disease states (%)		
Mild to moderate diabetes mellitus	9	8
Malignancy	81	80
Metastases from solid tumor	32	26
Moderate to severe liver	2	0
Myocardial infarction	2	4
Chronic pulmonary disease	16	13
Peripheral vascular disease ^a	38	21

^a statistically significant by chi² ($p < 0.05$)

acteristics, hospital characteristics and crude outcomes according to a NNPR < 1:2 versus a NNPR > 1:2. Two hundred twenty-five patients in nine hospitals were cared for in an ICU with a NNPR of one nurse caring for one or two patients (> 1:2), while 128 patients in 23 hospitals had a NNPR of one nurse caring for three or more patients (< 1:2). There was no significant difference in baseline patient characteristics between the two groups except for a greater incidence of peripheral vascular disease in patients with a NNPR < 1:2 (38% vs 21%, $p < 0.05$).

The overall unadjusted in-hospital mortality rate for esophageal resection was 8.1%. The unadjusted in-hos-

pital mortality rate for patients with a NNPR < 1:2 versus those with a NNPR > 1:2 was 15% versus 5.6% ($p = 0.009$). The median LOS for patients with a NNPR < 1:2 versus those with a NNPR > 1:2 was 15 days (IQR 11–27) versus 9 days (IQR 1.8–13) ($p < 0.001$). The total hospital cost for patients with a NNPR < 1:2 versus those with a NNPR > 1:2 was \$24,915 (IQR \$18,665–\$40,688) versus \$15,209 (IQR \$13,252–\$20,587) ($p < 0.001$).

Multivariate analysis of primary outcome variables

Table 2 reports the results of multiple logistic regression analysis for the three primary outcomes, in-hospital mortality, in-hospital LOS and total hospital cost, after adjusting for demographic factors, comorbid disease, severity of illness, type of procedure, hospital volume and surgeon volume.

In-hospital mortality

There was no significant difference in the risk of in-hospital mortality between patients with a NNPR > 1:2 and those with a NNPR < 1:2 (OR 0.7, 95% CI 0.3–2.0) after adjusting for other univariate predictors of mortality. Low hospital volume was the strongest independent predictor of in-hospital mortality (OR 4.3, 95% CI 1.3–14.1, $p < 0.009$).

Length of stay

There was a 39% (95% CI, 19–61%; $p < 0.001$) increase in in-hospital LOS for patients with a NNPR < 1:2 compared to patients with a NNPR > 1:2. Other independent predictors for increased LOS were low surgeon volume ($p < 0.001$), age ($p = 0.004$) and emergent ad-

Table 2 Multivariate association of patient characteristics and ICU characteristics with in-hospital mortality, length of stay and total hospital cost following esophageal resection

^a Odds ratio and 95% confidence interval

^b statistically significant by $p < 0.05$

^c Outcomes associated with age are expressed as percent increase per year

^d Risk associated with urgent and emergent admission is relative to elective admission

Patient characteristics	Risk of in-hospital mortality, adjusted OR (95% CI) ^a	Increase in hospital length of stay, adjusted % increase from median (95% CI)	Increase in total hospital cost, adjusted % increase from median (95% CI)
Patient characteristics			
Age	0.99 (0.95–1.03) ^c	0.7(0.2–1.22) ^{b,c}	0.6 (0.1–1.0) ^{b,c}
Male sex	0.88 (0.3–2.4)	–	3.7(–9.8 to 19)
Race	–	–12.8(–25.4 to 2.0)	–
Transthoracic esophagectomy	2.0 (0.6–8.0)	–2.5(–18 to 16)	–3 (–18 to 14)
Urgent admission ^d	0.9 (0.2–3.4)	23 (–4 to 58)	9 (–14 to 38)
Emergent admission ^d	0.4 (0.1–1.4)	49 (20–88) ^b	42 (15–75) ^b
Hospital characteristics			
Nurse to patient ratio > 1:2 at night	0.7(0.3–2.0)	39 (19–61) ^b	32 (14–52) ^b
Low hospital volume	4.3(1.3–14.1) ^b	9 (–7 to 27)	–7 (–19 to 8)
Low surgeon volume	1.6(0.6–4.3)	–19 (–7 to 30) ^b	–19 (–29 to 6) ^b

Table 3 Multivariate association of postoperative complications and a night-time nurse-to-patient ratio > 1:2 versus < 1:2 (NNPR night-time nurse-to-patient ratio, CI confidence interval)

Complication	NNPR > 1:2 (%)	NNPR < 1:2 (%)	Odds ratio (95% CI)	<i>p</i> value
Respiratory				
Pneumonia	8	16	2.4 (1.2–4.7)	0.012
Reintubation	12	25	2.5 (1.4–4.5)	0.001
Aspiration	22	25	1.2 (0.7–2.0)	0.5
Infectious				
Septicemia	1.8	6.2	3.7 (1.1–12.5)	0.04
Postoperative infection	4	5.5	1.4 (0.5–3.8)	0.5
Other				
Myocardial infarction	0.9	0.8	0.9 (0.08–9.7)	0.9
Cardiac arrest	0	0.8	1.2 (0.6–2.2)	0.6
Surgical complications	8	17	1.9 (0.9–3.8)	0.08
Acute renal failure	2.7	5.5	2.1 (0.7–6.4)	0.2

mission ($p < 0.001$). Using multi-level hierarchical modeling (clustering), the point estimate for increased LOS associated with a NNPR < 1:2 remained the same, but the confidence interval expanded to include zero [39% increase in LOS (95% CI –8 to 109%; $p = 0.11$)].

Total hospital cost

Multivariate analysis demonstrated a 32% (95% CI, 14–52%, $p < 0.001$) increase in direct hospital cost for patients with a NNPR < 1:2 versus patients with a NNPR > 1:2. This corresponds to an increase of \$4810 for patients with a NNPR < 1:2 from the median cost of \$15,209 for patients with a NNPR > 1:2. Other predictors of increased cost were the following: low surgeon volume ($p = 0.002$), age ($p = 0.03$), emergent admission ($p = 0.002$). Once again, when the clustering function was applied the confidence interval expanded to include zero but the point estimate remained unchanged [32% increase in cost (95% CI, –6 to 88%; $p = 0.11$)].

Complications

Table 3 reports the risk of development of postoperative complications previously associated with increased mortality in those patients with a NNPR < 1:2 versus a NNPR > 1:2. Patients with a NNPR < 1:2 had an increased risk of reintubation (OR 2.6, 95% CI, 1.4–4.5, $p = 0.001$), pneumonia (OR 2.4, 95% CI 1.2–4.7; $p = 0.012$), and septicemia (OR 3.6, 95% CI 1.1–12.5; $p = 0.04$).

Discussion

This observational study demonstrates a significant increase in morbidity and resource utilization for patients receiving postoperative care in intensive care units with

a single nurse caring for more than three ICU patients at night (< 1:2). A night-time nurse-to-patient ratio (NNPR) < 1:2 was associated with a 39% increase in LOS (4 days) and a 32% increase in direct hospital cost (\$4810). Several postoperative complications, including reintubation, pneumonia and septicemia, were associated with a NNPR < 1:2, and may explain the increased resource utilization.

These results add to a growing body of evidence that ICU nurse staffing can have a significant impact on patient outcomes [6, 15, 16, 17, 18, 19, 20, 21, 22]. We have previously shown that having a lower nurse to patient ratio during the day in patients undergoing abdominal aortic surgery is associated with increased risk of pulmonary complications and ICU length of stay [6]. In addition, many other investigators have shown an association between nurse staffing and patient outcomes. Fridkin et al. found that a reduction in the nurse-to-patient ratio from 1:1 to 1:2 independently increased the risk for catheter-related bloodstream infection [15]. Garfield et al. studied outcomes related to staffing in a high-dependency unit and concluded a nurse-to-patient ratio of 2:3 may be insufficient, and recommend a nurse-to-patient ratio of 1:2 [16]. An observational study by Blegen et al. found that total hours of care from all nursing personnel for all inpatient units within a hospital were associated directly with the rates of decubitus ulcers, complaints and mortality [17]. Archibald et al. found that the nosocomial infection rate in a pediatric cardiac ICU was inversely associated with the nursing hours:patient day ratio.

The results of this study address a particular aspect of the impact of nursing on patient outcomes: nurse staffing at night. Nursing care takes on an increased importance at night, when physician and ancillary service staffing is typically decreased. As the number of patients each nurse cares for increases, the time that can be devoted to each patient decreases. By reducing the time available to devote to direct patient care, the decreased level of care from low nurse-to-patient ratios

may lead to pulmonary and infectious complications that may account for increased LOS and cost for postoperative patients. Efforts of hospital policy makers to reduce costs by reducing nurse staffing may therefore be counter-productive, endeavors resulting in increased patient morbidity and increased health care cost.

We acknowledge there are several limitations to the conclusions of this study. Although we report a statistically significant increase in LOS and cost with a NNPR < 1:2, when the statistical analysis included multi-level hierarchical modeling (clustering function) [14], the 95% confidence intervals were widened, resulting in a *p* value greater than the acceptable level for significance (*p* < 0.05). This additional manipulation of the data is meant to correct for clustering of outcomes within a hospital by decreasing the degrees of freedom in the regression mode to the number of hospitals rather than the number of patients. Even with this stringent model, there was a trend towards significance, and this result is most likely due to an insufficient sample size rather than a true lack of difference.

Another potential for bias in this study is the accuracy of coding in administrative databases. Errors in coding of comorbid disease and complications could affect the results if they are systematic. A previous analysis of the quality of the Maryland HSCRC database in a random sample of coding at a single institution demonstrated the coding of complications associated with in-hospital mortality to be 96% accurate. Furthermore, we only analyzed complications that were determined prospectively to be independently associated with adverse patient outcomes and we previously validated the coding of these complications through a review of medical records [4].

The different methods of obtaining patient and ICU data could have been another source of potential bias. In order to minimize this bias, the data abstraction was blinded to hospital name, ICU characteristics and patient outcome. Although we did not use a prospective scoring system to adjust for severity of illness (e.g., APACHE score), the multivariate analysis for each primary outcome was adjusted for the nature of admission – elective, urgent or emergent. There was a significant association between emergent admission status and outcomes validating the adjustment of severity of illness using these methods. While some residual confounding regarding severity of illness may be present, this would probably be random and thus bias the study toward the null hypothesis.

Another limitation is our inability to adjust completely for pre-ICU care and post-ICU care. The com-

plications that were significantly associated with a NNPR < 1:2 (pneumonia, reintubation and septicemia) are all medical complications most likely to be impacted by postoperative care rather than surgical complications that might be a direct result of intraoperative care. The impact that a NNPR < 1:2 has on LOS was on total hospital LOS and not simply ICU length of stay. Only severe postoperative complications will necessitate increased ICU stay, whereas most complications increase the overall hospital stay. This may be one mechanism by which a NNPR < 1:2 in the ICU was associated with an increased risk of developing specific complications and an increased total hospital LOS.

Finally, the validity of our ICU survey instrument may be considered a limitation. We utilized a previously developed questionnaire about ICU organization and staffing [4, 9]. Content validity was established by having the instrument independently reviewed by five intensive care physicians to determine if each question captured the intended domain. In addition, the results of this study are similar to the results of another study using the same survey instrument supporting the validity of the instrument to measure important characteristics of ICU organization. The most important limitation of our survey was the absence of questions regarding total nursing experience, ICU nursing experience or nursing certification. Our survey evaluated nurse-to-patient ratios: a relatively simple measure of nurse staffing. Some or all of these additional variables may, in fact, be as important as nurse-to-patient ratios in preventing complications and increased resource utilization. In addition, we conducted our survey in 1996, in the middle of the period for which we have patient data. Hospitals could have changed their nurse-to-patient ratios either before or after the survey, introducing bias.

This statewide observational study demonstrates that decreased nurse staffing at night (nurse-to-patient ratio less than 1 to 2) is associated with postoperative complications, increased LOS and increased health care cost. The results of this study are important because they identify a relatively straightforward health policy change (instituting a nurse-to-patient ratio of greater than or equal to one-to-two at night) that is practically achievable, and will probably improve both clinical and economic outcomes for post-surgical patients. Further research is needed to evaluate how specific characteristics and processes of nursing care further impact clinical and economic outcomes in high-risk surgery patients.

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