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

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 patients 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, 2.5-4.5 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, z-test. Wilcoxon rank-sum test and simple linear regression. Univariate predictor variables with a p value 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-