Association Between Nursing Workload and Mortality of Intensive Care Unit Patients

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Purpose: To investigate differences in mortality of intensive care unit (ICU) patients according to the ratio between total patient care demands and nurse staffing.

Design: Observational, prospective study. Patients consecutively admitted in the medical-surgical ICU of a Greek hospital over a 1-year period were enrolled.

Methods: The Therapeutic Intervention Scoring System (TISS)-28 was used for measuring patient care demands. Daily sum of TISS-28 of patients and daily number of nurses were considered for estimating median and peak patient exposure to nursing workload. According to the values of median and peak patient exposure to nursing workload, patients were divided into three groups (low, medium, and high). Logistic regression was used for evaluating the associations between mortality during ICU length of stay and median or peak patient exposure to nursing workload, after adjusting for patient clinical severity.

Findings: 396 patients were included and 102 died. Differences in ICU mortality between high and low groups of median and peak patient exposure to nursing workload, although not statistically significant, were clinically remarkable, both when all patients were studied and when medical and surgical patients were separately studied.

Conclusions: Consideration of individual differences in patient acuity might add sensitivity to the detection of associations between nurse understaffing and ICU mortality.

Clinical Relevance: The findings indicate that not only differences among nurse characteristics, but also differences in patient care demands, are important when investigating the effect of nurse understaffing on mortality of ICU patients. Proper nurse staffing levels should be based on the estimation of total patient acuity, rather than on the absolute number of patients.

[Key words: nursing, intensive care unit, mortality, nursing workload, patient acuity, nurse staffing]

In recent years, there has been worldwide interest about the effect of nurse staffing on quantifiable patient outcomes. Understaffing has come as a consequence of both a decreasing number of available nurses, because of cost-containment efforts and an increasing number and acuity of patients (Ewart et al., 2004; Parker, Wyatt, & Ridley, 1998). Infection and decubitus ulcer rates, personnel errors, length of stay and mortality of patients have been studied as quality and safety indicators sensitive to understaffing (Carayon & Gurses, 2005). Mortality has the most robust operational definition and has been the most commonly used outcome. In multicentre studies conducted in hospitalized patients, in-hospital mortality has been reported to be inversely associated with nurse staffing levels (Aiken, Clarke, Sloane, Sochalski, & Silber, 2002; Sasichay-Akkadechanunt, Scalzi, & Jawad, 2003).
Considering organizational or patient variability across hospital departments, further evaluation of the association between nurse staffing and mortality at the unit or ward level is necessary for drawing specific conclusions. Intensive care units seem to be an ideal setting for addressing this association, because mortality rate, intensity of nursing care required from patients, and sensitivity of patients to lapses in care is expected to be high (Needleman & Buerhaus, 2003; Numata et al., 2006). Factors possibly responsible for an inverse association between nurse staffing and mortality include decreased patient surveillance hindering the early detection of adverse events, increased personnel errors, delayed weaning from mechanical ventilation, and increased hospital-acquired infection rate (Carayon & Gurses, 2005; Tarnow-Mordi, Hau, Warden, & Shearer, 2000). However, the findings of multicentre studies conducted in ICU patients have not supported the presence of a significant independent association between nurse staffing levels and in-hospital mortality (Amaravadi, Dimick, Pronovost, & Lipsett, 2000; Dimick, Swoboda, Pronovost, & Lipsett, 2001; Metnitz, Reiter, Jordan, & Lang, 2004; Pronovost et al., 2001).

Inability to detect associations between nurse staffing and mortality in the ICU might be attributed to many methodologic disadvantages, such as retrospective collection of data, presence of confounding factors which are difficult to control, difficulties in capturing dynamic nurse staffing conditions, and the effect of medical staffing contribution (Numata et al., 2006). Moreover, mortality might not be sensitive as an outcome measure, while in-hospital mortality might be affected by the care patients receive after being discharged from an ICU.

Besides nurse-to-patient ratio (usually expressed as a dichotomous variable, <1:2 and >1:2), which has been the most common nurse staffing measure used in studies, more sensitive measures have been used, such as night-time nurse-to-patient ratio, registered nurse-to-patient ratio and number of years of nurses’ clinical experience (Amaravadi et al., 2000; Cho, Ketefian, Barkauskas, & Smith, 2003; Tourangeau, Giovannetti, Tu, & Wood, 2002). However, these measures are focused on nursing staff and none takes into account the individual differences regarding ICU patient care demands. Absolute number of patients might not be a reliable measure of total patient acuity, because the same number of occupied beds might correspond to quite different nursing intensity at the unit level.

The aim of this study was to investigate differences in patient mortality during ICU stay according to patient exposure to nursing workload. Estimation of this exposure was based on the ratio between patient care demands at the unit level and nurse staffing level.

Methods

Design, Participants, and Setting

This was an observational, single-center, prospective study and a convenience sample was used. Patients consecutively admitted in the general ICU of an academic, tertiary care, Greek hospital from October 2005 to September 2006 were included in the study. This was a 14-bed ICU, to which medical and surgical adult patients are admitted. Both registered and licensed practical nurses are employed in this unit and, because of the small number of registered nurses, nursing tasks (except for administrative ones) do not differ considerably between registered and licensed practical nurses. The majority of nurses are employed in the ICU for more than 5 years.

Data Collection

Age, gender, type of admission (medical or surgical), diagnosis at admission, duration of mechanical ventilation, ICU length of stay, and mortality during ICU stay of all patients were recorded. For the evaluation of patient clinical severity, the Acute Physiology and Chronic Health Evaluation (APACHE) II score, which ranges between 0–91 points, was used. This score is made up of three components: acute physiologic score (0–60 points), age adjustment (0–6 points), and chronic health adjustment (0–25 points). APACHE II scores were calculated by one of the researchers (P.K.) during the first 24 hours after ICU admission, in accordance with the recommendations of Knaus, Draper, Wagner, and Zimmerman (1985).

For the measurement of patient care demands, The Therapeutic Intervention Scoring System (TISS-28) of each patient was estimated daily (Miranda, de Rijk, & Schaufeli, 1996) by two of the researchers (A.S. and C.S.). TISS-28 is a simplified version of the original TISS (76 items) and ranges between 0–78 points. Items are divided into seven categories: basic activities (0–14 points), ventilatory (0–7 points), cardiovascular (0–26 points), renal (0–8 points), neurologic (0–4 points) and metabolic support (0–9 points), and specific interventions (0–10 points). Both TISS-28 and TISS-76 are based on the principle that the number of therapeutic interventions is related to clinical severity, thus the higher a patient’s score, the more nursing time spent on this patient’s care (Padiha et al., 2007). Data were collected at the same time each day, indicating patient care needs and respective interventions performed during the previous 24-hour period. Because of the clinical expertise of the researchers (employed for >12 years in the ICU) and the fact that the estimation of TISS-28 is based on objective clinical interventions (e.g., arterial line, mechanical ventilation), measurement of inter-rater reliability was waived.

At the unit level, daily nursing workload associated with direct care demands of patients (tasks directly related to patient care, excluding e.g., documentation, maintenance of equipment, or administrative work) was calculated by adding TISS-28 scores of all patients in the ICU during this day. This sum was divided by the number of nurses employed in the ICU during the three shifts of this day to estimate daily workload per nurse. At the patient level, daily workload per nurse for the days a patient was in the ICU constituted patient exposure to nursing workload. For
statistical comparisons, median and peak patient exposure to nursing workload were used, which were defined as the median and highest value of daily workload per nurse respectively for the days a patient stayed in the ICU (median was preferred instead of mean, because values of daily workload per nurse were not expected to be normally distributed). Thus, one value of each of these variables was attributed to each patient.

For patients readmitted to the ICU during the conduction of the study, only their first time of admission was taken into consideration regarding estimation of median and peak patient exposure to nursing workload and outcome. At the patient level, exclusion of following times of admission was considered necessary for avoiding both inclusion of a patient more than once in the dataset (and respective correlated errors) and the introduction of bias because of the effect of care this patient received outside the ICU (before readmission) on his or her outcome. However, at the unit level, daily care demands of readmitted patients could not be ignored, thus following times of admission were considered in terms of their contribution to daily workload per nurse.

Ethical Considerations

Permission to conduct this study was obtained by the nursing agency and the ethical committee of our hospital. The purpose and method of our study were explained to all nurses and verbal consent was obtained. To assure anonymity and confidentiality of staff and patients, collected data were not transferred to or discussed with other medical and nursing staff.

Data Analysis

The Statistical Package for Social Sciences (SPSS 15.0) was used for statistical analysis of collected data. The Kolmogorov-Smirnov test was used to check normality of distribution of continuous variables. For comparisons between survivors and nonsurvivors, student’s t test and the Mann-Whitney U test were used for continuous normally and non-normally distributed variables respectively. The Chi-square test was used for categorical variables (with Yates’ continuity correction for variables having two categories).

According to the values of median patient exposure to nursing workload, patients were divided into three, equal in number, groups (low, medium and high, 132 patients in each group). Binary logistic regression (enter method) was used for evaluating the association between ICU mortality and median patient exposure to nursing workload. ICU mortality was the dependent variable, while median patient exposure to nursing workload, entered as a categorical, three-group variable with low exposure being the reference group, was the independent variable. The APACHE II score was entered as an independent, continuous variable in order to adjust for patient clinical severity. Three logistic regression models were constructed: one for all patients, one for medical patients, and one for surgical patients.

By following the same procedure, patients were divided into three, equal in number, groups according to the values of peak patient exposure to nursing workload, and logistic regression was used for evaluating the association between ICU mortality and peak patient exposure to nursing workload. Model chi-square and Hosmer-Lemeshow chi-square (goodness-of-fit) tests were estimated for the evaluation of all logistic regression models.

Findings

Data are presented as mean ± standard deviation (median) for continuous variables and number (%) for categorical ones. Of 396 patients included in the study, 14 were readmitted one or more times to the ICU (readmission rate 3.5%). During the study period, nurse-to-patient ratio ranged from 1:1 to 1:2 during the morning shift, 1:1.5 to 1:2.5 during the evening shift and 1:2 to >1:3 during the night shift. Mean daily workload per nurse was 24.8±7.9 (23.5) TISS-28 points. Values of median and peak patient exposure to nursing workload ranged from 17.8–30.8 to 20.5–35.8 TISS-28 points per nurse, respectively.

There were 267 (67.4%) male and 196 (49.5%) medical patients. Regarding medical patients, the most common causes of admission were trauma (35.1%), respiratory failure (27.3%), nontraumatic cerebral damage (9.3%) and severe infection (7.8%). Regarding surgical patients, 60.6% were elective cases, while the most common causes of admission were cardiac surgery (37.6%), trauma (19.7%), abdominal surgery (16.2%) and neurosurgery (11.9%). Mean age was 53.5±19.4 (56.0) years and mean APACHE II score was 13.4±5.5 (13.0) points. APACHE II scores ranged from 3–35 points. Mean duration of mechanical ventilation was 7.2±9.8 (3.0) days and mean length of ICU stay was 9.2±15.9 (4.0) days. One hundred two (25.8%) patients died during their ICU stay. Nonsurvivors had a significantly higher APACHE II score, were mechanically ventilated for a longer time, and stayed longer in the ICU, while the percentage of medical patients who died was significantly higher in non-survivors (Table 1).

Regarding groups of median patient exposure to nursing workload, mortality of all patients (medical and surgical) increased from 22.0% in the low-exposure group (21.9 TISS-28 points per nurse) to 25.0% in the medium-exposure group (21.9–25.8 TISS-28 points per nurse) and reached up to 28.8% in the high-exposure group (>25.8 TISS-28 points per nurse). In all 64 surgical patients were in the low-exposure group, 61 in the medium- and 75 in the high-exposure group. Mortality of surgical patients increased from 12.5% in the low-exposure group to 13.1% in the medium-exposure group and reached up to 17.3% in the high-exposure group, while mortality of medical patients increased from 30.9% in the low-exposure group to 35.2% in the medium-exposure group and reached up to 43.9% in the high-exposure group. Despite these increases, differences in adjusted ICU mortality among groups did not
reach statistical significance neither when all patients were studied nor when medical and surgical patients were separately studied (Table 2).

Regarding groups of peak patient exposure to nursing workload, mortality of all patients increased from 20.4% in the low-exposure group (<25.4 TISS-28 points per nurse) to 25.8% in the medium-exposure group (25.4–29.8 TISS-28 points per nurse) and reached up to 31.1% in the high-exposure group (>29.8 TISS-28 points per nurse). In all 66 surgical patients were in the low-exposure group, 63 in the medium- and 71 in the high-exposure group. Mortality of surgical patients increased from 12.1% in the low-exposure group to 15.9% in the medium-exposure group and reached up to 21.1% in the high-exposure group, while mortality of medical patients increased from 28.8% in the low-exposure group to 34.8% in the medium-exposure group and reached up to 42.6% in the high-exposure group. Despite these increases, differences in adjusted ICU mortality among groups did not reach statistical significance neither when all patients were studied nor when medical and surgical patients were separately studied (Table 3).

### Table 1. Patient Differences According to Intensive Care Unit Mortality

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Survivors (294)</th>
<th>Nonsurvivors (102)</th>
<th>P</th>
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<tbody>
<tr>
<td>Gender (male)</td>
<td>196 (66.7%)</td>
<td>71 (69.6%)</td>
<td>0.672</td>
</tr>
<tr>
<td>APACHE II score (points)</td>
<td>12.9±5.4 (13.0)</td>
<td>14.7±6.3 (14.0)</td>
<td>0.004</td>
</tr>
<tr>
<td>Type of admission (medical)</td>
<td>127 (43.2%)</td>
<td>69 (67.6%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Duration of mechanical ventilation (days)</td>
<td>6.8±8.9 (2.0)</td>
<td>8.4±11.1 (4.5)</td>
<td>0.029</td>
</tr>
<tr>
<td>Length of Intensive Care Unit stay (days)</td>
<td>7.9±9.9 (4.0)</td>
<td>12.8±26.2 (5.0)</td>
<td>0.035</td>
</tr>
</tbody>
</table>

**Note.** aMeasured in Therapeutic Intervention Scoring System—28 points per nurse; badjusted for Acute Physiology and Chronic Health Evaluation II score of patients; clow-exposure group as reference; OR = odds ratio; CI = confidence interval.

### Table 2. Logistic Regression Analysis: Intensive Care Unit Mortality as Dependent Variable, Median Patient Exposure to Nursing Workload as Independent Variable

<table>
<thead>
<tr>
<th>Peak patient exposure to nursing workload</th>
<th>ORs for ICU mortality (95% CI)</th>
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<tbody>
<tr>
<td></td>
<td>All patients (396)</td>
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<tr>
<td></td>
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<tr>
<td>High-exposure group</td>
<td>1.74 (0.98–3.08)</td>
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<tr>
<td>Medium-exposure group</td>
<td>1.37 (0.77–2.45)</td>
</tr>
</tbody>
</table>

**Note.** aMeasured in Therapeutic Intervention Scoring System—28 points per nurse; badjusted for Acute Physiology and Chronic Health Evaluation II score of patients; clow-exposure group as reference group; OR = odds ratio; CI = confidence interval.

All six logistic regression models explained a significant percentage of variance in the data (for all models, significance of the model chi-square test was <0.028) and indicated a satisfactory fit to the data (for all models, significance of Hosmer-Lemeshow chi-square test was >0.248).

### Discussion

Our study was the first reported to use the estimation of patient care demands, instead of absolute number of patients, for evaluating the association between nurse staffing and mortality. Individual care demands were found to vary significantly among ICU patients, because daily TISS-28 ranged from 13–54 points during the study period. Thus, it seems plausible that the number of nurses needed for a particular day can be more reliably predicted on the basis of these demands, rather than on absolute number of patients. Moreover, compromised quality of care is expected to come as a consequence of imbalance between total patient acuity and the amount of care nurses are capable to provide. Worth noting is that, in the only known previous study about the ICU in which in-hospital mortality was found to be positively associated with nursing workload (Tarnow-Mordi et al., 2000), nursing requirement per shift was used instead of nurse-to-patient ratio. This was based on recommendations of the United Kingdom Intensive Care Society, according to which the highest number of nurses required was determined by patient clinical status (ranging from 0.5 to 2.0 nurses per patient).

Although differences detected in the present study did not reach statistical significance, they cannot be ignored from a clinical point of view. First, there was a clearly progressive increase in ICU mortality along the three groups of median and peak patient exposure to nursing workload. Second, in the high-exposure groups of median and peak patient exposure to nursing workload, the odds for ICU mortality increased by 39% and 74% respectively, compared to low-exposure groups. Based on the effect sizes found in the present study, a retrospective statistical power
analysis was conducted (Power and Precision 2.0, Biostat, Inc.) to determine the smallest sample sizes (sum of surgical and medical patients) which would allow detecting statistically significant differences in ICU mortality between low and high groups of patient exposure to nursing workload (alpha=0.05, two-tailed, power=0.80). These sample sizes are 1,466 (733 for each group) and 518 (259 for each group) patients for median and peak patient exposure to nursing workload, respectively. Especially the second one is considerably smaller than the sample sizes enrolled in two previous studies (ranging from 2,606 to 26,186 patients), in which nurse-to-patient ratio was used and no significant association between nurse staffing and mortality was found (Metnitz et al., 2004; Pronovost et al., 2001). This finding possibly indicates that patient acuity per nurse can be a more sensitive measure than is absolute number of patients per nurse regarding detection of associations between nurse staffing and adverse patient outcomes.

Variations in hospital outcomes generally arise from three sources: patient characteristics, quality of care, and random causes (Stone & Tourangeau, 2003). This means that individual mortality risk is a major confounding factor that has to be adjusted. Besides the high acuity and high mortality rate of ICU patients, another advantage of investigating the effect of nurse staffing on this population is the availability of standardized methods for adjusting this risk. Clinical severity scores are generally based on the quantification of abnormality of multiple physiologic variables. However, because these scores (including APACHE II, which was used in this study) are calculated on the day of ICU admission, they cannot allow investigators to distinguish patients who deteriorate during ICU stay (thus being more likely to die) from those who improve, thus mortality risk adjustment may be insufficient.

We separately studied the effect of patient exposure to nursing workload on ICU mortality among medical and surgical patients, because these two patient populations are often heterogeneous regarding characteristics and outcomes. Surgical patients are expected to be healthy enough to sustain an operation, while medical patients are often more susceptible to adverse events because of higher clinical severity. In this study, medical patients were significantly younger (p=0.048), had a higher APACHE II score (p=0.029), stayed longer in the ICU (p=0.017) and their ICU mortality was higher (35.2% vs. 16.5%, p<0.001). Despite these differences, increases in the odds for ICU mortality among groups of median and peak patient exposure to nursing workload did not differ much between these two patient populations. This finding may imply that the degree of generalizability of our findings is relatively high, because this is not expected to be significantly affected by differences in medical-surgical population mix among ICUs of different hospitals.

Several limitations are recognized in this study. First, no statistical power analysis calculations were conducted before the beginning of the study for determining necessary sample size. The main reason for this was that our methodology differed considerably from that of previous studies (individual care demands were not considered in any of them); therefore, we could not use their findings for calculating the effect size for our study. Moreover, statistically significant associations could be found in only one of them (Tarnow-Mordi et al., 2000). Second, nursing workload measurement systems have been criticized in terms of validity, reliability, and capability of capturing the complexity and entirety of nursing activities. Although TISS (of 76 or 28 items) has been widely reported in the literature, it cannot be considered a “gold standard” for measuring patient acuity, because it inevitably indicates not the entirety but only a portion of actual patient-care demands. Third, mortality during ICU stay, although not affected by the care patients receive outside the ICU, can be affected by physicians’ decisions to discharge patients from the ICU (in case of premature discharge).

A fourth limitation is that registered nurse-to-patient ratio and clinical experience of nursing staff are possibly more sensitive measures than are absolute number of nurses for detecting differences in patient mortality according to nurse staffing. Fifth, patient care demands as well as nurse staffing may fluctuate considerably among shifts of the same day, thus cannot be captured by averaged daily workload per nurse, which represents the whole day. Sixth, cutoff points for patient division into three groups according to median and peak patient exposure to nursing workload can be considered arbitrary.

Conclusions

Although no statistically significant differences were detected among the present findings, these may offer a new perspective on detecting associations between nurse understaffing and ICU patient mortality by indicating the importance of considering individual care demands of patients. Adequately matching total patient acuity with an efficient number of nursing staff and keeping patient exposure to nursing workload at a low level is expected to increase safety and improve survival rate of ICU patients. We strongly recommend duplicating this study through the enrollment of larger samples, which are necessary for detecting statistically significant differences between exposure to nursing workload and mortality. The use of other nursing workload measurement systems, in which different aspects of patient care demands are taken into account, is also suggested.

Clinical Resources

Nursing Workload and ICU Mortality


References


