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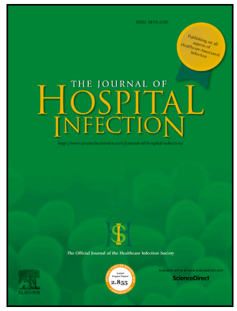

Association of nurse staffing and nursing workload with ventilator-associated pneumonia and mortality: a prospective, single-center cohort study

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Summary

Background: Nurse understaffing and increased nursing workload have been associated with increased risk of adverse patient outcomes and even mortality.

Aim: The aim of this study was to determine whether nurse staffing and nursing workload are associated with ventilator-associated pneumonia and mortality.

Methods: This prospective, observational cohort study was conducted in a single tertiary-level teaching hospital in Finland during 2014–2015. The association between nurse staffing, nursing workload and prognosis was determined by using daily nurse-to-patient ratios, Therapeutic Intervention Scoring System and Intensive Care Nursing Scoring System scores, and Intensive Care Nursing Scoring System indices. Ventilator-associated pneumonia was defined according to the Centers for Disease Control and Prevention criteria.

Results: Evaluable data was available for 85 patients. The overall ventilator-associated pneumonia and 28-day mortality rates were 23.5% and 35.3%, respectively. Nurse staffing, measured as the daily lowest nurse-to-patient ratio ($p = 0.006$) and median Intensive Care Nursing Scoring System index ($p = 0.046$), were significantly lower in patients with ventilator-associated pneumonia. In addition, nursing workload, measured as median scores obtained by the Therapeutic Intervention Scoring System ($p = 0.009$) and Intensive Care Nursing Scoring System ($p = 0.03$), was significantly higher in infected patients. The median ($p = 0.02$) and daily highest ($p = 0.03$) Intensive Care Nursing Scoring System scores were significantly higher in non-survivors.

Conclusions: Lower nurse staffing and increased nursing workload are associated with ventilator-associated pneumonia and mortality demonstrating that adequate staffing is a prerequisite for the availability and quality of critical care services.

Keywords: nurse staffing, nursing workload, ventilator-associated pneumonia, mortality, critical care

Background

Currently, there is a growing awareness of the importance of appropriate staffing; the need for critical care services has grown substantially over the last few decades [1] and if the current trend persists, the demand for critical care services will continue to increase over the decades ahead [2-3]. The complexity of today's patient calls for appropriate staffing for the prevention of adverse patient outcomes. Meanwhile, workload is increasing due to fewer human resources [2].

Nursing understaffing and increased nursing workload have been associated with increased risk of adverse patient outcomes (e.g., falls, decubiti, medication administration errors, healthcare-associated infections, unplanned extubations, mortality) as well as nurse burnout and job dissatisfaction [4-11]. Traditionally, Therapeutic Intervention Scoring System (TISS), Nine Equivalents of Nursing Manpower Use Score, Critical Care Patient Dependency Tool, and Nursing Activities Score have been the most commonly used instruments for estimating the nursing workload and costs in intensive care units (ICUs) [12-15]. Correspondingly, nurse-to-patient (N/P) ratio, patient-to-nurse ratio, bed-to-nurse ratio, and hours of care have been the most commonly used parameters in the estimation of nurse staffing [7-8, 10, 16].

A new Intensive Care Nursing Scoring System (ICNSS) was developed in 2000 and later validated to provide the type of daily real-time information on the patients (e.g., altered tissue perfusion, elimination, fluid volume, heart rhythm, communication, physical mobility, impaired gas exchange, skin integrity, ineffective airway clearance, sleep pattern disturbance, pain, fatigue, anxiety/fear) and their relatives (e.g., distress) that specifies the needs for preventive, supportive, complementary or compensatory nursing and determines the nursing workload [17]. Based on the results of criteria and content validation, ICNSS is a suitable instrument to be used with the TISS score; ICNSS has explained a similar percentage of variation of the admission scores of Acute Physiology and Chronic Health Evaluation (APACHE II), New Simplified Acute Physiologic Score (SAPS II) as TISS and discriminated between survivors and non-survivors among medical and surgical patients [17]. The basic assumption in the ICNSS is that the more severe the health problem, the more demanding, time-consuming and nurse-dependent interventions will be needed [17]. In addition, the more severely ill the patient is, the higher the patient's risk of death.

ICNSS index is the ratio of estimated number of nurses needed based on the scoring (ICNSS score per nurse <32 points corresponding to a N/P ratio of 1:1; ICNSS score per nurse <39 points corresponding to a N/P ratio of 1.5:1; ICNSS score per nurse >40 points corresponding to a N/P ratio of 2:1) and the actual number of nurses observed which demonstrates N/P ratios in relation to the intensity of nursing care. An ICNSS index value higher than 1 corresponds to understaffing in relation to the need (patient complexity) while less than 1 corresponds to overstaffing.

The relationship between nurse staffing, nursing workload (intensity of nursing care included) and adverse patient outcomes in critical care setting is largely unknown. Therefore, we were interested to determine whether nurse staffing and nursing workload are associated with ventilator-associated pneumonia (VAP) and mortality.

Methods

This prospective observational cohort study was conducted in a 900-bed tertiary-level teaching hospital in Finland. The hospital has an adult, closed, mixed medical-surgical ICU with 22 beds (four 1-bed rooms, three 2-bed rooms, four 3-bed rooms) and admits approximately 2000 patients per year for a mean stay of three days. Patients were attended by intensivists that were present in the ICU for 24 hours per day, 7 days a week (from 7:30 AM to 2:30 PM two residents and 5 specialists, and from 2:30 PM to 7:30 AM one resident or specialist). During the study period, the median N/P ratio was 1.2:1. Furthermore, multidisciplinary rounds (including intensivists, an infectious disease physician, radiologists, a gastrointestinal surgeon, an internal medicine physician and a nurse in charge) were performed daily on 5 days a week. As recommended, standard procedures applied throughout the study period included daily sedative interruption, daily assessment of readiness to extubate, semi recumbent positioning, daily oral care with chlorhexidine (0.12%), strict hand hygiene (including alcohol-based hand rub) and use of protective personal equipment according to standards (either surgical masks or FFP3 respirators, equivalent to N95 respirator, during aerosol-producing procedures; goggles; single-use gloves and a gown/apron based on an assessment of the risk of transmission and contamination; voluntary influenza vaccination), and prophylactic treatments for peptic ulcer disease and deep venous thrombosis [18]. In the department, empirical antibiotic treatment is guided by systematic resistance surveillance of bacteria. In the treatment of individual patients, microbiological specimens of different foci are frequently obtained and antimicrobial agents are changed when necessary according to resistance patterns. During the last four years there have been two MRSA findings among 2 900 respiratory specimens. One patient had a *vanB* producinb*Enterococcus faecium* in a pus specimen and another patient a KPC-producer in sputum, pus, and urine cultures. During the last four years all our *Pseudomonas aeruginosa* strains in blood and pus specimens have been tobramycin sensitive.

Study population

During the study period (from October 2014 to the beginning of June 2015), all consecutive adult patients who were admitted to the mixed medical-surgical ICU and received invasive ventilation over 48 hours were recruited and monitored daily for the development of VAP until ICU discharge or death. Patients who met the prospectively defined criteria of VAP were included in the analysis unless they met one of the following exclusion criteria: pneumonia diagnosis or the presence of tracheostomy already at the time of ICU admission, human immunodeficiency virus or significant immune suppression (including prolonged neutropenia [> 1 week] or chronic steroid therapy [≥ 40 mg of prednisolone daily for a duration of > 4 weeks]). The study was approved by the relevant academic center and reviewed by the ethical committee of Northern Ostrobothnia Hospital District, Oulu University Hospital, Oulu, Finland. Written informed consent was obtained from participants or their next of kin prior to inclusion in the study (Declaration of Helsinki 2013).

Definitions

Centers for Disease Control and Prevention criteria [19] were used to assess the presence or absence of opacities compatible with pneumonia. Chest radiographs were acquired on day 0 (the day of a diagnosis, D0), on two days (D-2) prior to the occurrence of VAP, and up to two days (D+2) post D0. These radiographs were re-evaluated afterwards in multidisciplinary meetings including a chest radiologist, two intensivists, and an infectious disease physician. Both lungs were assessed separately to determine the presence or absence of pneumonia or atelectasis. Only the first episode of VAP was considered.

Data collection and outcomes

The following demographic and clinical data were collected: admission diagnosis, age, gender, and daily highest and lowest temperatures and leucocyte counts for each calendar day. In addition, APACHE II, SAPS II, and Sequential Organ Failure Assessment (SOFA) scores were recorded daily [20-22]. The clinical outcomes collected included the incidence of VAP and 28-day mortality.

Nurse staffing level was recorded by collecting the total number of nurses and patients for each calendar day including morning, evening and night shifts. The daily N/P ratio was determined by dividing the total number of nurses by the total number of patients for each calendar day. Daily TISS (range 10–60 points) and ICNSS (range 16–64 points) scores were recorded. Daily ICNSS index was determined by dividing the total ICNSS score by the total number of available nurses during a given day. Following the methodology in Hugonnet *et al.* [6], the level of nurse staffing and nursing workload were recorded at the D0 plus four days prior to the occurrence of VAP (D-4).

Data analysis

Demographic and clinical data are presented using frequencies and percentages and medians and quartiles (i.e., 25th and 75th percentiles). Nonparametric *t*-test was used to compare continuous variables. Friedman test was used to test change from D-4 to D0. Two-tailed *P*-value < 0.05 was considered as statistically significant. Receiver operating characteristic (ROC) curve and the area under the curve (AUC) were used to determine the associations between nurse staffing and workload with VAP and mortality. Statistical analyses were performed using SPSS 21.0 for Windows (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.). VAP rates were defined as the number of cases per 1,000 ventilator days [18-19].

Results

During the study period, 85 patients were included in the study (a detailed flow chart of the included patients has been presented elsewhere [23]). The majority of included patients were neurosurgical (41.2%) male (68.2%) patients with a median age of 64.0 (51.5-72.5) years. The median APACHE, SAPS and SOFA scores at admission were 20.0 (14.0-25.5), 47.0 (36.0-59.0) and 8.0 (6.0-10.0), respectively. The median ICU and hospital lengths of stay were 10.4 (5.9-16.7) and 19.5 (11.7-30.2) days, respectively, and the median durations of mechanical ventilation and antibiotic use were 6.3 (4.3-12.7) and 10.0 (6.0-16.0) days, respectively. During the study period, 23.5% of the included patients developed VAP (22.4/1,000 days of mechanical ventilation). The overall 28-day mortality rate was 35.3%. The 28-day mortality did not differ ($p = 0.42$) between patients with VAP (45.0%) and those without VAP (32.3%). There were no differences in case mix between patients with and without VAP, but those with VAP were younger and had lower SAPS II scores on admission and higher cumulative total TISS and ICNSS scores (Table I).

Across the study population, the median N/P ratio and ICNSS indices were 1.2 (1.2-1.3) and 1.3 (1.2-1.4), respectively. The daily lowest N/P ratio was significantly lower in patients with VAP than in those without VAP (1.0 [0.9-1.0] vs. 1.0 [1.0-1.1], $p = 0.006$) (Table II). Accordingly, the median ICNSS index was significantly higher in patients with VAP (1.4 [1.3-1.5] vs. 1.3 [1.2-1.4], $p = 0.046$). The daily lowest N/P ratios and highest ICNSS indexes at the D0 plus four days prior to VAP are presented in Table III. The level of nurse staffing did not change over time, however. In addition, daily N/P ratios and ICNSS indexes did not differ between non-survivors and survivors.

The median TISS score was 37.0 (32.5–43.5). The median TISS score was significantly higher (41.5 [36.6-46.0] vs. 36.5 [32.0-40.8], $p = 0.009$) in patients with than without VAP (Table II). The daily TISS scores between the days D-4 to DO are presented in the Table IV. The median daily lowest TISS scores were significantly ($p = 0.02$) higher in non-survivors than in survivors (Table III).

The median ICNSS score was 30.0 (29.0–32.0). The median ICNSS score was significantly higher in patients with VAP than in those without VAP (31.0 [30.0-34.0] vs. 30.0 [28.1-32.0], $p = 0.03$) (Table II). The daily median ($p = 0.02$) and the daily highest ($p = 0.03$) ICNSS scores were significantly higher in non-survivors than survivors (Table III). The daily ICNSS scores between the days D-4 to DO are presented in the Table IV.

In the ROC analysis, the AUC values for the daily lowest N/P ratio and the median ICNSS index, TISS and ICNSS scores for VAP were 0.3 (95% confidence interval [CI], 0.2-0.4), 0.7 (95% CI, 0.5-0.8), 0.7 (95% CI, 0.6-0.8), and 0.7 (95% CI, 0.5-0.8), respectively (Table II). Correspondingly, the AUC values for the median and the daily highest ICNSS scores for the 28-day mortality were 0.6 (95% CI, 0.5-0.8) and 0.6 (95% CI, 0.5-0.8), respectively (Table III).

Discussion

The main finding of this study is that understaffing and increased nursing workload are associated with VAP and mortality. To the best of our knowledge, this is the first study that has prospectively evaluated nurse staffing and nursing workload as potential risk factors for VAP, using not only N/P ratio but also ICNSS index and TISS and ICNSS scores. That nursing staff requirement was systematically analyzed using two different scores yielding equal results is in contrast to previous studies and represents the main strength of this study.

The incidence of VAP was in line with previous studies [6, 24] even though the daily N/P ratio was lower than previously reported rate (1.2 [1.2-1.3] vs. 1.9 [1.8-2.2]) [6] and the duration of mechanical ventilation (3 vs. 6 days) and the ICU length of stay (10 vs. 5-6 days) were almost 2-fold compared to the corresponding values in previous literature [6, 24]. In line with previous literature, the daily lowest N/P ratio was significantly lower in patients with VAP than those without VAP [25]. However, our findings are not comparable with those reported in Hugonnet *et al*. [6, 25] due to variability in VAP definitions, sample size (*n* = 2,470 vs. 85), admission diagnosis (medical vs. medical-surgical patients), APACHE scores (24 [19-30] vs. 20.0 [14.0-25.59] points), and mortality (31.7% vs. 35.3%).

In this study, nurse staffing was measured using not only N/P ratio but also ICNSS index, which demonstrates N/P ratios in relation to the intensity of nursing care. The median ICNSS index was significantly higher in patients with VAP than in those without VAP. Most of the time during the study period (65.6%), however, the level of nurse staffing was at the standard level. Nursing workload, measured as the median TISS and ICNSS scores, was significantly higher in patients with VAP than in patients without VAP. In a previous study, ICU-acquired infection increased the TISS scores 4.1-fold and 1.9-fold in patients with and without infection at the time of ICU admission, respectively [27]. In addition, nursing acuity score at admission has been found to increase infection risk [25].

Contrary to the results by Blot *et al*. [24], in which a ratio of 1 to 1 seemed to be associated with decreased risk for VAP, Hugonnet *et al*. [6] found that a higher N/P ratio was associated with a >30% risk reduction (incidence rate ratio 0.69 [95% CI 0.50-0.95]) for all ICU-acquired infections, and that maintaining a N/P ratio above 2.2 would ultimately lead to avoidance of 26.7% of all infections. However, this threshold may be challenging to achieve due to the decreasing human resources and increasing demands for critical care services. Since 1967 the gold standard for nurse staffing levels in intensive care has been one nurse for each patient.

In the future, a few additional aspects of nurse staffing with relevance to patient care in the ICU need to be considered. Firstly, instead of focusing solely on nurse staffing level, more attention should be paid on what adequate staffing entails [26]. The factors that have been considered in relation to adequate staffing include, for example, healthcare staffs' knowledge, level of training [4], professional expertise and certification [4, 8], disproportion between the capacity of wards and the number of patients, help provided for students and new colleagues on the ward, and performance of unnecessary tasks [28-29]. In this study, the majority of the nurses had earned at least a bachelor's degree after having completed 12 years of education (basic and upper secondary schools) but did not hold a special degree in emergency and intensive care or CCRN-E™ certification due to lack of specialist training in Finland. In prior literature, the nurses' level of education and their ICU experience (> 1 year) have been associated with lower mortality and better knowledge scores [10, 31], respectively. In this study, the median level of ICU work experience was 10.0 (5.0–19.3) years. Secondly, more attention should be paid to bundle compliance; increased nursing workload, manifest, for example, in lack of time, lack of personnel, and the lack of clear responsibilities, has resulted in noncompliance with basic VAP prevention guidelines [30]. In addition, strict compliance with infection prevention elements should be monitored [32]. According to Blot *et al*. [24], efforts to reduce the number of days at risk should be a priority in the prevention of VAP. Moreover, presence of a full-time hospital epidemiologist has been associated with lower VAP rates [31]. Thirdly, more attention should be paid to technology. For example, automated systems have reduced the duration of mechanical ventilation and ICU length of stay [33].

The fact that this was an observational single-center study with a limited sample size and VAP rate may limit the generalizability of our results. In addition, we did not take into account the contribution of medical staff (i.e., residents [*n* = 2], specialists [*n* = 9]) or other personnel (i.e., head nurses [*n* = 4], practical nurses [*n* = 8], advanced practice provider [*n* = 1], porters [*n* = 4], physiotherapists [*n* = 1.5], secretaries [*n* = 4], sterile processing technicians [*n* = 4], pharmacist [*n* = 1], study nurse [*n* = 1], and IT administrator [*n* = 1]) or the presence of students and trainees, which may have had an impact on nursing efficiency and workload. However, the results of this prospective observational study are in line with previous literature [6, 24-25]. In addition, nurse staffing was at the standard level most of the time and the nurses were supported by the organization of the unit (e.g., time and structure of daily multidisciplinary rounds, staff levels, staff allocation system) and by interprofessional relationships (e.g., doctor-nurse relationship, interprofessional communication, supportive and collegial working environment), which are known to influence, for example, critical care nurses' decision making. Another limitation is that we did not take into account bundle compliance and other confounding factors. On the other hand, a causal relationship of nursing workload and staffing on patient outcomes is challenging to demonstrate. The third important limitation is that all the included patients were exposed to the same N/P ratio, and it is impossible to determine the effect this may have had on the results. Generally, this limitation affects all studies dealing with this topic [6, 25]. Contrary to other studies, however, we calculated actual ratios instead of unit-based standards [24].

Conclusion

Lower staffing and increased nursing workload are associated with VAP and mortality demonstrating that adequate staffing is a prerequisite for the availability and quality of critical care services.

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None.

Conflict of interest

The authors declare that they have no competing interests.

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Table I. Clinical characteristics and case mix of included patients (n = 85).

	Patient without VAP (n = 65)	Patient with VAP (n = 20)	P -value
Age (years), median [a]	66.0 (54.5-73.0)	55.0 (42.0-66.3)	0.048*
Gender (male), No. (%)	44 (67.7)	15 (75.0)	0.592
Admission type (emergency), No. (%)	60 (92.3)	18 (90.0)	0.665
APACHE II at admission, median	20.0 (14.5-26.0)	17.5 (12.3-22.0)	0.074
APACHE II diagnostic category, No. (%)			0.451
Intracranial hemorrhage	11 (16.9)	2 (10.0)	
Sepsis	7 (10.8)	1 (5.0)	
Neurological	6 (9.2)	1 (5.0)	
Head trauma	5 (7.7)	1 (5.0)	
Heart valve surgery	4 (6.2)	0 (0.0)	
Infection	4 (6.2)	0 (0.0)	
Multiple trauma	4 (6.2)	2 (10.0)	
Seizure disorder	4 (6.2)	2 (10.0)	
Cardiac arrest	4 (6.2)	0 (0.0)	
Chronic cardiovascular disease	2 (3.1)	2 (10.0)	
Coronary artery disease	2 (3.1)	0 (0.0)	
Craniotomy for ICH/ SDH/ SAH	2 (3.1)	1 (5.0)	
Craniotomy for tumor	2 (3.1)	1 (5.0)	
Cardiovascular	1 (1.5)	1 (5.0)	
Chronic heart failure	1 (1.5)	0 (0.0)	
Diabetic ketoacidosis	1 (1.5)	0 (0.0)	
Dissecting thoracic / abdomina aneurysm	1 (1.5)	0 (0.0)	
Gastrointestinal	1 (1.5)	1 (5.0)	
Hemorrhagic shock / hypovolemia	1 (1.5)	0 (0.0)	
Metabolic / renal	1 (1.5)	1 (5.0)	
Peripheral vascular surgery	0 (0.0)	1 (5.0)	
Postoperative gastrointestinal	0 (0.0)	1 (5.0)	
Postoperative sepsis	0 (0.0)	1 (5.0)	
Postoperative cardiovascular	0 (0.0)	1 (5.0)	
Pulmonary embolus	1 (1.5)	0 (0.0)	
Operated (yes), No. (%)	30 (46.2)	12 (60.0)	0.315
SAPS II at admission, median	49.0 (37.0-62.0)	42.0 (25.2-52.0)	0.047
SOFA at admission, median	8.0 (6.0-10.0)	7.0 (5.0-9.8)	0.211
SOFA max, median	11.0 (9.5-13.0)	11.0 (10.0-13.0)	0.933
TISS total, median	377.0 (233.5-567.0)	713.0 (560.0-868.5)	<.001*
ICNSS total, median	852.5 (488.8-1425.5)	1508.0 (1108.8-1851.8)	0.001*

* Two-tailed P -value < 0.05 was considered as statistically significant.

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; SAPS II, New Simplified Acute Physiologic Score; SOFA, Sequential Organ Failure Assessment; TISS, Therapeutic Intervention Scoring System; ICNSS, Intensive Care Nursing Scoring System; VAP, ventilator-associated pneumonia.

Table II. Nursing workload and nurse staffing between patients with and without ventilator-associated pneumonia.

	Patient without VAP (*n* = 65)	Patient with VAP (*n* = 20)	P -value	AUC (95% CI)
N/P ratio				
Lowest	1.0 (1.0-1.1)	1.0 (0.9-1.0)	0.006*	0.3 (0.2-0.4)
Median	1.2 (1.2-1.3)	1.2 (1.2-1.3)	0.98	0.5 (0.4-0.6)
ICNSS index				
Highest	1.5 (1.4-1.7)	1.7 (1.5-2.0)	0.11	0.6 (0.5-0.8)
Median	1.3 (1.2-1.4)	1.4 (1.3-1.5)	0.046*	0.7 (0.5-0.8)
TISS score				
Highest	49.0 (41.0-57.0)	53.0 (49.5-58.5)	0.13	0.6 (0.5-0.7)
Median	36.5 (32.0-40.8)	41.5 (36.6-46.0)	0.009*	0.7 (0.6-0.8)
ICNSS score				
Highest	36.0 (33.0-39.0)	38.0 (34.0-41.8)	0.09	0.6 (0.5-0.8)
Median	30.0 (28.1-32.0)	31.0 (30.0-34.0)	0.03*	0.7 (0.5-0.8)

* Two-tailed *P* -value < 0.05 was considered as statistically significant.

Abbreviations: AUC, area under curve; CI, confidence interval; ICNSS, Intensive Care Nursing Scoring System; N/P ratio, nurse-to-patient ratio; TISS, Therapeutic Intervention Scoring System; VAP, ventilator-associated pneumonia.

Table III. Nursing workload and nurse staffing between survivors and non-survivors.

	Survivor (n = 55)	Non-survivor (n = 30)	P -value	AUC (95% CI)
N/P ratio				
Lowest	1.0 (1.0-1.1)	1.0 (1.0-1.1)	0.68	0.5 (0.4-0.7)
Median	1.2 (1.2-1.3)	1.2 (1.2-1.3)	0.82	0.5 (0.4-0.6)
ICNSS index				
Highest	1.5 (1.4-1.7)	1.5 (1.4-1.8)	0.52	0.5 (0.4-0.6)
Median	1.3 (1.2-1.4)	1.3 (1.2-1.5)	0.11	0.6 (0.4-0.7)
TISS score				
Highest	50.0 (41.0-57.0)	50.5 (43.3-59.0)	0.59	0.5 (0.4-0.7)
Median	36.5 (32.0-41.0)	39.5 (33.9-47.0)	0.58	0.6 (0.5-0.3)
ICNSS score				
Highest	35.0 (33.0-38.0)	38.5 (33.0-41.3)	0.03*	0.6 (0.5-0.8)
Median	30.0 (28.0-31.3)	31.0 (29.0-34.0)	0.02*	0.6 (0.5-0.8)

* Two-tailed P -value < 0.05 was considered statistically significant.
Abbreviations: AUC, area under curve; CI, confidence interval; ICNSS, Intensive Care Nursing Scoring System; N/P ratio, nurse-to-patient ratio; TISS, Therapeutic Intervention Scoring System; VAP, ventilator-associated pneumonia.

Table IV. Nursing workload and nurse staffing at the D0 (the day of a diagnosis) plus four days (D-4) prior to ventilator-associated pneumonia.

	Patient with VAP (*n* = 20)	*P* -value*
N/P ratio		0.99
D-4 (*n* = 16)	1.3 (1.1-1.4)	
D-3 (*n* = 18)	1.2 (1.1-1.4)	
D-2 (*n* = 20)	1.2 (1.1-1.4)	
D-1 ((*n* = 20)	1.2 (1.0-1.3)	
D0 (*n* = 20)	1.2 (1.1-1.2)	
ICNSS index		0.23
D-4 (*n* = 17)	1.3 (1.1-1.2)	
D-3 (*n* = 18)	1.4 (1.2-1.5)	
D-2 (*n* = 20)	1.3 (1.2-1.5)	
D-1 ((*n* = 20)	1.3 (1.2-1.5)	
D0 (*n* = 20)	1.4 (1.3-1.5)	
TISS score		0.68
D-4 (*n* = 18)	42.0 (33.0-49.0)	
D-3 (*n* = 18)	39.0 (35.0-46.5)	
D-2 (*n* = 20)	40.0 (34.0-47.0)	
D-1 ((*n* = 20)	40.0 (35.0-46.0)	
D0 (*n* = 20)	41.0 (35.0-47.0)	
ICNSS score		0.94
D-4 (*n* = 17)	23.4 (21.1-25.4)	
D-3 (*n* = 18)	22.8 (31.0-36.0)	
D-2 (*n* = 20)	23.4 (18.9-26.1)	
D-1 ((*n* = 20)	22.8 (19.0-26.3)	
D0 (*n* = 20)	24.2 (23.0-28.0)	

* Friedman test was used to test change from D-4 to D0.
Abbreviations: AUC, area under curve; CI, confidence interval; ICNSS, Intensive Care Nursing Scoring System; N/P ratio, nurse-to-patient ratio; TISS, Therapeutic Intervention Scoring System; VAP, ventilator-associated pneumonia.