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The proportion of understaffing and increased nursing workload are associated with multiple organ failure: A cross-sectional study

Miia Jansson[1,2] | Pasi Ohtonen[3,4] | Hannu Syrjälä[5] | Tero Ala-Kokko[4,6,7]

[1]Research Group of Medical Imaging, Physics and Technology, University of Oulu, Oulu, Finland
[2]Oulu University Hospital, Oulu, Finland
[3]Division of Operative care, Oulu University Hospital, Oulu, Finland
[4]Medical Research Center Oulu, University of Oulu, Oulu, Finland
[5]Department of Infection Control, Oulu University Hospital, Oulu, Finland
[6]Division of Intensive Care, Department of Anesthesiology, Oulu University Hospital, Oulu, Finland
[7]Research Group of Surgery, Anesthesiology and Intensive Care, Medical Research Center Oulu, Oulu, Finland

Correspondence
Miia Jansson, Research Group of Medical Imaging, Physics and Technology, University of Oulu, Oulu, Finland.
Email: miia.jansson@oulu.fi

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Abstract

Aims: To determine whether nurse staffing and nursing workload are associated with multiple organ failure and mortality.

Design: A cross-sectional study.

Methods: This study was conducted in a single tertiary-level teaching hospital during 2008–2017. The association between nurse staffing, nursing workload and prognosis was determined using daily nurse-to-patient ratios, Therapeutic Intervention Scoring System scores, Intensive Care Nursing Scoring System scores and Intensive Care Nursing Scoring System indexes. In addition, the timing of intensive care unit admission was considered. Multiple organ failure was defined according to the Sequential Organ Failure Assessment score.

Results: During the study period, 10,230 patients were included in the final analysis. Generally, the mean daily highest Therapeutic Intervention Scoring System score and Intensive Care Nursing Scoring System score were significantly higher in patients with multiple organ failure and in non-survivors. The proportion of understaffing was significantly more common in patients with multiple organ failure than in those without. The mean daily lowest nurse-to-patient ratio and the mean daily highest Intensive Care Nursing Scoring System index did not differ between survivors and non-survivors. The levels of nursing associated with workload and understaffing were at their worst on weekends.

Conclusions: The proportion of understaffing and increased nursing workload are associated with multiple organ failure, demonstrating that an adequate level of nurse staffing in relation to patient complexity is a prerequisite for the availability and quality of critical care services. The proportion of understaffing did not differ between survivors and non-survivors.

Impact: This is the first study that evaluates nurse staffing and nursing workload as potential risk factors for multiple organ failure and mortality. There is a need to

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ensure that intensive care units are consistently staffed based on real patient needs, 7 days a week and that personnel and services are available at all times for high-risk patients.

KEYWORDS

critical care, mortality, multiple organ failure, nurse staffing, nursing, nursing workload

1 | INTRODUCTION

Multiple organ failure (MOF) is the main cause of mortality and intensive care unit (ICU) resource use among patients with non-cardiac surgery, multiple trauma and severe burns (Ciesla et al., 2005; Fröhlich et al., 2014; Kallinen, Maisniemi, Böhling, Tukiainen, & Koljonen, 2012; Lobo et al., 2011) requiring prolonged mechanical ventilation and length of ICU stay (Dewar, Tarrant, King, & Balogh, 2013; Sauaia et al., 2014). The mortality rate associated with MOF varies between 24–36% and increases with the number of affected organs (Dewar et al., 2013; Sauaia et al., 2014).

Currently, there is a growing awareness of the importance of appropriate staffing. Moreover, if the current trend persists, the demand for critical care services will continue to increase in the decades to come (Adhikari, Fowler, Bhangwanjee, & Rubenfeld, 2010; Needham et al., 2005). The complexity of today's patients calls for appropriate staffing to prevent adverse patient outcomes. Meanwhile, the workload of health professionals is increasing due to fewer human resources (Adhikari et al., 2010; Hugonnet, Harbarth, Sax, Duncan, & Pittet, 2004; Needham et al., 2005).

2 | BACKGROUND

Nursing understaffing (using the nurse-to-patient [N/P] ratio), increased nursing workload (using the Therapeutic Interventions Scoring System [TISS] score and the Nursing Activities Score [NAS]) and severity of the patient illness (SAPS II) have been associated with unfavourable patient safety outcomes, most markedly in-hospital mortality (Aiken et al., 2014; Driscoll et al., 2018; Haegdorens, Van Bogaert, De Meester, & Monsieurs, 2019; Needleman et al., 2011; Nogueira, Domingues, Poggetti, & Sousa, 2014; Padilha et al., 2007; Padilha, Sousa, Queijo, Mendes, & Miranda, 2008). On the other hand, patient gender (male), the presence of pulmonary failure and the number of injured body regions have been associated with increased nursing workload (Nogueira et al., 2014). In addition, ICU-acquired infection has increased TISS scores 4.1-fold (Ylipalosaari, Ala-Kokko, Laurila, Ohtonen, & Syrjälä, 2006).

An Intensive Care Nursing Scoring System (ICNSS) has been developed to describe patients' and their relatives' needs for preventive, supportive, complementary or compensatory nursing and has since been validated and applied with medical and surgical patients to determine the nursing workload (Pyykkö et al., 2004a, 2004b). Each health problem and the corresponding workload are scored on a four-point scale. The total nursing workload is the sum of nursing scores (range: 16–64 points). The basic assumption in the ICNSS is that the more severe the health problem, the more demanding, time-consuming and nurse-dependent the needed interventions (Pyykkö et al., 2004b).

The ICNSS index is the ratio of the estimated number of nurses needed based on the ICNSS scoring (ICNSS score per nurse ≤ 22 points corresponding to an N/P ratio of 0.5:1; ICNSS score per nurse ≤ 32 points corresponding to an N/P ratio of 1:1; ICNSS score per nurse ≤ 39 points corresponding to an N/P ratio of 1.5:1; and ICNSS score per nurse ≥ 40 points corresponding to an N/P ratio of 2:1) and the actual number of nurses observed. An ICNSS index value higher than 1 corresponds to understaffing in relation to patient needs, while less than 1 corresponds to overstaffing.

The relationship between nurse staffing, nursing workload and adverse patient outcomes in critical care setting is mainly focused on clinical outcomes (e.g. hospital-acquired infections, pulmonary complications, reintubation, in-hospital mortality) and economic outcomes (e.g. the length of stay, costs) (Amaravadi, Dimick, & Lipsett, 2000; Daud-Gallotti et al., 2012; Dimick, Swoboda, Pronovost, & Lipsett, 2001; Hugonnet, Chervolet, & Pittet, 2007; Hugonnet, Uckay, & Pittet, 2007; Lee et al., 2017; Neuraz et al., 2015). However, matching nurse staffing to patients' and their relatives' needs for preventive, supportive, complementary or compensatory nursing care is rarely described (Jansson, Syrjälä, & Ala-Kokko, 2019; Needleman et al., 2011; Neuraz et al., 2015). We were, therefore, interested in determining whether nurse staffing (using the ICNSS indexes in addition to N/P ratios) and nursing workload (using the ICNSS and TISS scores) are associated with MOF and MOF-related in-hospital mortality. The timing of ICU admission was also considered.

3 | THE STUDY

3.1 | Aims

To determine whether nurse staffing and nursing workload are associated with MOF and mortality.

3.2 | Design

This was a cross-sectional study. This article followed the STROBE reporting standard for cohort studies (Von Elm et al., 2007).

3.3 | Participants

This study was conducted in a 900-bed tertiary-level teaching hospital in Finland in 2018. 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 2,000 patients per year for a mean stay of three days. Patients were attended by intensive care specialists who were present in the ICU for 24 hr per day, 7 days a week. Furthermore, multidisciplinary rounds were performed daily, 5 days a week.

All admissions were identified from the hospital database. Patients were eligible for inclusion if they were adults (≥18 years), were admitted to the ICU between 1 January 2008 and 31 December 2017 (N = 13,720) and had complete data sets regarding nurse staffing and nursing workload. Because our focus was on high-risk critically ill patients, patients with low-risk elective surgery (e.g. cardiac surgery or neurosurgery) were excluded to reduce case mix heterogeneity. In total, 10,230 patients met the inclusion criteria and were included for further analysis (Figure 1).

3.4 | Data collection

MOF was defined by the Sequential Organ Failure Assessment (SOFA) score and was recorded prospectively for all included patients between 11 p.m.–12 p.m. daily, beginning on the day of admission until ICU discharge or death (Vincent et al., 1996). Only the first episode of MOF was considered.

The SOFA score consists of scores from six organ systems (respiratory, cardiovascular, renal, liver, coagulation and central nervous system [CNS]), graded from 0–4 according to the degree of dysfunction or failure noted in the clinical medical records. Auto-filled fields were checked daily by the nurse and IT support. A score of 3 or above for one of the organ systems was defined as a failure of the organ in question (e.g. PaO_2 on mechanical ventilation [kPa], platelets [10^3/µl], Glasgow Coma Scale [if on sedatives, assumed GCS estimated from sedatives], bilirubin [mg/dL], mean arterial pressure [MAP < 70 mmHg] or administration of any vasoactive agents required [mcg/kg/min], creatinine [mg/dL or urine output]). MOF was defined as organ failure for at least two of the listed organs or systems.

Secondary outcomes were MOF-related mortality (death of any cause in MOF patients). The prospectively recorded SOFA, SAPS II, APACHE II, TISS and ICNSS scores were collected daily, from admission to discharge and on the basis of the medical records (Keene & Cullen, 1983; Knaus, Draper, Wagner, & Zimmerman, 1985; Le Gall, Lemeshow, & Saulnier, 1993; Pyykkö et al., 2004a; Vincent et al., 1996). Only the daily highest ICNSS and TISS scores for each calendar day were considered.

The level of nurse staffing was recorded by collecting the total number of nurses and patients throughout each calendar day (i.e. 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. Only the daily lowest N/P ratios for each calendar day were considered. The daily ICNSS index was determined by dividing the sum of nurses needed by the sum of available nurses during each day. Only the daily highest indexes for each calendar day were considered.

3.5 | Ethical considerations

The study was approved by the relevant academic centre (Declaration of Helsinki 2013). Ethics approval was not required for the registered study.

3.6 | Data analysis

Only the worst values for each calendar day were used; in the literature, a lower level of staffing on a given day has been associated with increased infection risk two to four days (Hugonnet, Uckay, et al., 2007). The level of nurse staffing and nursing workload were

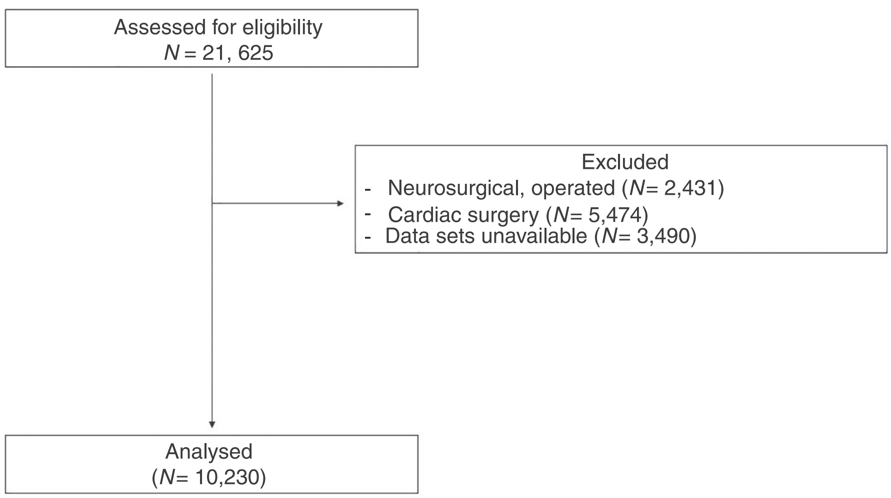

FIGURE 1 Flow chart of included patients

recorded from admission to discharge in patients without MOF and from admission to the day of diagnosis (D0) in patients with MOF. The demographic and clinical data are presented using frequencies and percentages and means and standard deviations (SDs) or medians and quartiles (i.e. 25th and 75th percentiles), as appropriate. An independent-samples *t* test was applied for comparison of the continuous variables. In addition, Fisher exact test was used to compare categorical variables.

Additionally, multivariable linear regression models were used to get adjusted results between MOF (no/yes), hospital mortality (no/yes) and a subgroup of MOF patients (early- vs. late-stage MOF) for TISS scores, ICNSS scores, N/P ratios and ICNSS indexes. Age, gender, APACHE II scores, admission type (emergency/elective), surgery (no/yes) and N/P ratios were used as adjustable variables, except for the N/P ratios for the models of the N/P ratio itself and the ICNSS index. The results for the Student's *t* test and linear regression model are presented as the difference between means with a 95% confidence interval (95% CI).

Shifts were categorized as understaffed (yes/no) if they had N/P ratios <1 and ICNSS indexes >1 and a shift's adjusted impact on MOF and hospital mortality was calculated using a multivariable logistic regression model. Age, gender, APACHE II score, admission type (emergency/elective) and surgery (no/yes) were used as adjustable variables. The results of the logistic regression model are presented as an odds ratio (OR) with a 95% CI.

A receiver operating characteristic (ROC) curve and area under the curve (AUC) were used to assess the ability of the daily highest ICNSS scores, to predict MOF-related 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.). Two-tailed *P* value < 0.05 was considered statistically significant.

TABLE 1 Clinical characteristics at admission and outcome of patients with and without multiple organ failure

Characteristics	Patient without MOF (*N* = 8,204)	Patient with MOF (*N* = 2,026)	MOF within 48 hr (*N* = 1,735)	MOF > 48 hr after ICU admission (*N* = 291)
Age (years), mean (*SD*)	57.88 (18.18)	61.35 (15.58)	61.58 (15.48)	59.94 (16.08)
Gender (male), No. (%)	4,946 (60.31)	1,339 (66.09)	1,141 (65.76)	198 (68.04)
Specialty				
Surgery, No. (%)	4,156 (50.68)	845 (41.71)	688 (39.65)	157 (53.95)
Neurosurgery (not operated), No. (%)	863 (10.52)	341 (16.83)	297 (17.12)	44 (15.12)
Internal Medicine, No. (%)	1932 (23.56)	597 (29.47)	539 (31.07)	58 (19.93)
Gynaecology/Obstetrics, No. (%)	267 (3.26)	8 (0.39)	5 (0.29)	3 (1.03)
Infectious Diseases, No. (%)	13 (0.16)	5 (0.25)	5 (0.29)	0 (0.00)
Otorhinolaryngology, No. (%)	503 (6.13)	46 (2.27)	37 (2.13)	9 (3.09)
Neurology, No. (%)	458 (5.58)	184 (9.08)	164 (9.45)	20 (6.87)
Other, No. (%)	5 (0.06)	0 (0.00)	0 (0.00)	0 (0.00)
Admission type (emergency), No. (%)	7,076 (86.28)	1956 (96.54)	1674 (96.48)	282 (96.91)
Surgical (yes), No. (%)	2,549 (31.08)	405 (19.99)	342 (19.72)	63 (21.65)
APACHE II score, mean (*SD*)	13.35 (5.89)	19.41 (6.56)	20.00 (6.55)	15.87 (5.42)
SAPS II score, mean (*SD*)	30.14 (12.75)	44.57 (14.11)	16.06 (14.09)	35.70 (10.56)
Ventilator days, median (Q1, Q3)	0.00 (0.00, 0.15)	1.63 (0.50, 4.07)	1.52 (0.46, 3.60)	3.11 (10.8, 6.29)
Length of ICU stay (days), median (Q1, Q3)	1.08 (0.78, 2.03)	4.94 (2.74, 8.94)	4.53 (2.56, 7.83)	9.80 (6.58, 14.13)
Length of hospital stay (days), median (Q1, Q3)	8.15 (4.46, 14.64)	13.87 (7.88, 23.33)	12.72 (7.20, 21.65)	20.21 (12.56, 34.13)
Hospital mortality, No. (%)	310 (3.78)	385 (19.00)	328 (18.90)	57 (19.59)

Abbreviations: APACHE II, Acute Physiology and Chronic Health Evaluation Score; ICU, Intensive Care Unit; MOF, Multiple organ failure; SAPS II, Severity of the patient illness score.

3.7 | Validity and reliability

The SOFA score has been validated for describing the severity of organ dysfunctions in a mixed medical-surgical ICU population and has since been further validated and applied in various patient groups, being used for mortality prediction and as a prognostic marker in end-of-life practices with a good interrater accuracy (García-Gigorro et al., 2018; Orr, 2020; Vincent & Moreno, 2010). Based on the results of criteria and content validation, the ICNSS is a suitable instrument to be used with the TISS score; the ICNSS has explained a similar percentage of variation of the admission scores of APACHE II, SAPS II as TISS and discriminated between survivors and non-survivors among medical and surgical patients (Pyykkö et al., 2004b).

4 | RESULTS

4.1 | Demographics

During the study period, 10,230 patients were included in the final analysis (Figure 1). Most patients were non-elective (88.2%) males (61.5%) with a mean age of 58.57 (*SD* 17.75) years (Table 1). The mean APACHE II score was 14.55 (*SD* 6.50) points, while the mean SAPS II score was 33.00 (*SD* 14.25) points at admission. The overall in-hospital mortality was 6.8%. The daily distribution of nurse staffing, nursing workload, day of ICU admissions and day of MOF diagnoses over the study period are described in Table 2.

4.2 | Incidence of MOF

The overall incidence of MOF was 117 per 1,000 ICU days. In this series, 85.64% (*N* = 1,735) of MOF cases occurred in 48 hr of ICU admission (early-stage MOF), while 14.36% (*N* = 291) occurred >48 hr after ICU admission (late MOF). In the subgroup analysis, 60.11% of patients without MOF, 58.93% of patients with early-stage MOF and 56.01% of patients with late-stage MOF were admitted outside office hours (time schedule: from 4.00 p.m. to 8.00 a.m.).

4.3 | Nursing workload

The mean daily highest TISS score was 31.57 (*SD* 11.70) across the study population, while the mean daily highest ICNSS score was 29.27 (*SD* 5.17) respectively. Generally, the mean daily highest TISS and ICNSS scores were significantly higher in patients with MOF than in those without (Table 3). In the subgroup analysis, both the mean daily highest TISS and ICNSS scores were significantly higher in patients with late-stage MOF. In addition, the mean daily highest ICNSS score was slightly higher on weekends (Table 2).

Both the mean daily highest TISS and ICNSS scores were significantly higher in non-survivors than in survivors (Table 4). In the

TABLE 2 The daily distribution of nurse staffing, nursing workload, day of ICU admissions and day of MOF diagnoses over the study period

Weekday	MOF within 48 hr (*N* = 1,735)						MOF > 48 hr after ICU admission (*N* = 291)					
	TISS score, mean (*SD*)	ICNSS score, mean (*SD*)	N/P ratio, mean (*SD*)	ICNSS index, mean (*SD*)	Day of ICU admission, *N* (%)	Day of diagnosis, *N* (%)	TISS score, mean (*SD*)	ICNSS score, mean (*SD*)	N/P ratio, mean (*SD*)	ICNSS index, mean (*SD*)	Day of ICU admission, *N* (%)	Day of diagnosis, *N* (%)
Monday	31.27 (11.19)	31.72 (5.36)	1.13 (0.37)	1.08 (0.27)	245 (14.12)	271 (15.62)	44.68 (8.31)	35.32 (3.70)	0.75 (0.16)	1.23 (0.22)	49 (16.84)	41 (14.09)
Tuesday	31.16 (11.62)	32.30 (5.42)	1.03 (0.19)	1.13 (0.23)	248 (14.29)	244 (14.06)	42.54 (8.52)	35.89 (4.58)	0.74 (0.18)	1.30 (0.25)	44 (15.12)	46 (15.81)
Wednesday	31.50 (11.53)	32.04 (4.71)	1.02 (0.44)	1.17 (0.23)	241 (13.89)	249 (14.35)	42.35 (9.43)	35.94 (5.35)	0.77 (0.14)	1.29 (0.17)	46 (15.81)	31 (10.65)
Thursday	32.50 (11.53)	32.06 (4.98)	1.02 (0.20)	1.14 (0.21)	260 (14.98)	240 (13.83)	42.96 (10.37)	35.57 (4.67)	0.78 (0.13)	1.27 (0.23)	49 (16.84)	46 (15.81)
Friday	30.42 (11.35)	31.28 (4.83)	1.03 (0.21)	1.14 (0.21)	234 (13.49)	255 (14.70)	42.11 (9.64)	35.42 (4.63)	0.75 (0.16)	1.27 (0.23)	44 (15.12)	53 (18.21)
Saturday	30.62 (11.54)	32.34 (4.99)	0.99 (0.17)	1.19 (0.23)	250 (14.41)	226 (13.03)	45.61 (8.16)	36.24 (4.52)	0.74 (0.13)	1.31 (0.20)	37 (12.71)	33 (11.34)
Sunday	29.78 (11.85)	31.64 (4.93)	1.08 (0.23)	1.10 (0.24)	257 (14.81)	250 (14.41)	45.02 (7.84)	36.66 (4.42)	0.76 (0.12)	1.29 (0.28)	22 (7.56)	41 (14.09)

Abbreviations: ICNSS, Intensive Care Nursing Scoring System; MOF, Multiple organ failure; N/P ratio, nurse-to-patient ratio; TISS, Therapeutic Intervention Scoring System.

TABLE 3 The level of nursing workload and nurse staffing in patients with and without MOF

Variable†	Patients without MOF (*N* = 8,204)	Patients with MOF (*N* = 2026)	Difference (95% CI)	*p*-value‡	Adjusted results	95% CI difference for adjusted results	MOF within 48 hr (*N* = 1735)	MOF > 48 hr after ICU admission (*N* = 291)	Difference (95% CI)	*p*-value‡	Adjusted results	95% CI difference for adjusted results
TISS score	28.78 (9.94)	32.48 (12.04)	−3.70 (−4.20 to −3.19)	<.001	2.36§	1.85 to 2.87	30.63 (11.48)	43.51 (8.99)	−12.88 (−14.03 to −11.49)	<.001	12.74§	11.30 to-14.18
ICNSS score	28.84 (4.96)	32.46 (5.16)	−3.62 (−3.87 to −3.38)	<.001	2.87§	2.62 to 3.12	31.90 (5.04)	35.82 (4.53)	−3.93 (−4.54 to −3.31)	<.001	4.13§	3.49 to 4.78
N/P ratio	0.99 (0.20)	1.02 (0.27)	−0.03 (−0.04 to −0.02)	<.001	0.04§	−0.03 to −0.05	1.04 (0.28)	0.91 (0.17)	0.13 (0.1 to 0.17)	<.001	−0.14§	−0.17 to −0.10
N/P ratio < 1	4,612 (56.3)	1578 (77.9)		<.001	2.59¶	2.29 to 2.92	1,319 (76.1)	259 (89.0)		<.001	2.29¶	1.55 to 3.38
ICNSS index	1.17 (0.25)	1.15 (0.24)	0.01 (−0.0 to 0.02)	.09	−0.02§	−0.03 to −0.01	1.14 (0.23)	1.28 (0.25)	−0.15 (−0.17 to −0.11)	<.001	0.15§	0.12 to 0.18
ICNSS index > 1	6,122 (74.7)	1825 (90.1)		<.001	2.90¶	2.46 to 3.4	1549 (89.3)	276 (94.8)		.003	1.94¶	1.12 to 3.36

Abbreviations: CI, confidence interval; ICNSS, Intensive Care Nursing Scoring System; MOF, Multiple organ failure; N/P ratio, nurse-to-patient ratio; TISS, Therapeutic Intervention Scoring System.

†Data are presented using frequencies and percentages as well as means and standard deviations.

‡An Independent-Samples t-Test was applied for comparison of the continuous variables. In addition, Fisher exact tess was used to compare categorical variables.

§Difference.

¶Odds ratio.

subgroup analysis, the mean daily highest ICNSS score was significantly higher in non-survivors with early-stage MOF (Table 5). In the ROC analysis, the AUC values for the mean daily highest ICNSS scores for in-hospital mortality were 0.56 (95% CI 0.53–0.60) in patients with early-stage MOF and 0.55 (95% CI 0.47–0.63) in patients with late-stage MOF. Correspondingly, the AUC values for the mean daily highest TISS scores for in-hospital mortality were 0.52 (95% CI 0.48–0.55) in patients with early-stage and 0.53 (95% CI 0.45–0.62) in patients with late-stage MOF.

4.4 | Nurse staffing

The mean daily lowest N/P ratio was 1.19 (*SD* 0.55) during the study period, while the mean daily highest ICNSS index was 0.99 (*SD* 0.22) respectively. Generally, 22.64% of shifts were understaffed according to the nurse-to-patient ratio, while 44.64% were understaffed in relation to patient needs. In general, the mean daily lowest N/P ratio was slightly lower, while the mean daily highest ICNSS index was slightly higher on weekends (Table 2).

In the subgroup analysis, the mean daily lowest N/P ratio prior to MOF was lower in patients with late-stage than those with early-stage MOF (Table 3). In addition, the mean daily highest ICNSS index was higher in patients with late-stage MOF. The proportion of N/P ratio <1 and ICNSS index >1 was significantly more common in patients with MOF than in those without. In the subgroup analysis, the proportion of N/P ratio <1 and ICNSS index >1 was significantly more common in patients with late-stage than those with early-stage MOF. The proportion of understaffing did not differ between survivors and non-survivors (Table 4).

The AUC values for the mean daily lowest N/P ratios for in-hospital mortality were 0.51 (95% CI 0.47–0.54) in patients with early-stage MOF and 0.46 (95% CI 0.38–0.54) in patients with late-stage MOF respectively. Correspondingly, the AUC values for the mean daily ICNSS index for in-hospital mortality were 0.52 (95% CI 0.49–0.56) in patients with early-stage MOF and 0.49 (95% CI 0.40–0.57) in patients with late-stage MOF.

5 | DISCUSSION

To the best of our knowledge, this is the first study that evaluated nurse staffing and nursing workload as potential risk factors for MOF and mortality. In contrast to the previous literature, the nurse staffing requirement was systematically analysed using two different scores, yielding equal results with a sufficient sample size. Our findings indicated that 22.64% of shifts were understaffed according to the nurse-to-patient ratio, while 44.64% were understaffed in relation to patient needs. In addition, the proportion of understaffing was more common in patients with MOF than those without and in non-survivors than in survivors. The levels of nursing workload and understaffing were at their worst on weekends, while MOF was diagnosed mainly on Mondays.

In our study, nursing workload (using the TISS and ICNSS scores) was significantly higher in patients with MOF than in those without. In general, the nursing workload was significantly higher in non-survivors than survivors. In the subgroup analysis, the mean daily highest ICNSS score was higher in non-survivors with early-stage MOF. Although it has been suggested that a qualified critical care nurse should be capable of managing a patient with 40–50 TISS-76 points (Keene & Cullen, 1983) and there is more than 95% chance that death is more likely to occur when the TISS-76 score per nurse is ≥52 points (Lee et al., 2017), there is no single and unique staffing level threshold value for TISS-72 nor ICNSS scores.

The proportion of understaffing (using N/P ratio <1) was more common in patients with MOF than in those without. In addition, the mean daily lowest N/P ratio and the mean daily highest ICNSS index were at their worst in patients with late-stage MOF in the subgroup analysis. In the literature, however, there is no single and unique value for a nurse staffing threshold because the optimal staffing level depends on both risk and costs. In 2007, 26.7% of all ICU-acquired infections were shown to have been preventable if the level of N/P ratio is maintained above 2.2 (Hugonnet, Chervolet, et al., 2007). In addition, an increase of the N/P ratio by 1 unit was associated with a >30% infection risk reduction (Hugonnet, Chervolet, et al., 2007), whereas Amaravadi et al. (2000) and Dimick et al. (2001) found that incidence of ventilator-associated pneumonia, reintubation rates and costs increased if the N/P ratio was below 0.5.

The proportion of understaffing (using the ICNSS index >1) was significantly more common in patients with MOF than in those without. In addition, the proportion of understaffing was slightly higher on weekends. The proportion of understaffing, however, did not differ between survivors and non-survivors.

Despite many years of research, the patient safety implications of the timing of admission has remained somewhat controversial. For instance, Bell and Redelmeier (2001) were the first to demonstrate that weekend hospital admissions were associated with higher in-hospital mortality. In addition, a recent meta-analysis confirms that weekend hospital admission are associated with a 19% relative increase in mortality compared with weekday admissions and across a variety of diagnoses (Pauls et al., 2017). In addition, the adjusted risk of death for ICU admission was shown to be greater on weekends than on weekdays (Galloway et al., 2018; Zajic et al., 2017).

Three potential mechanisms for the weekend effect have been identified in the literature: a decrease in the level of hospital staffing or experienced staff (Galloway et al., 2018), access to specialized diagnostics or therapies is reduced or delayed (Ranji, 2018) and/or the severity of or multiplicity of conditions is greater during weekends (Bell & Redelmeier, 2001), which is in line with our study findings. There is a need to ensure that ICUs are consistently staffed based on real patient needs, 7 days a week and that personnel and services are available at all times for high-risk patients. Accordingly, decision-making support systems for staffing

TABLE 4 The level of nursing workload and nurse staffing between survivors and non-survivors

Variable[†]	Patients without MOF (N = 8,204)						Patients with MOF (N = 2026)					
	Survivor (N = 7,892)	Non-survivor (N = 312)	Difference (95% CI)	p-value[‡]	Adjusted results	95% CI difference for adjusted results	Survivor (N = 1641)	Non-survivor (N = 385)	Difference (95% CI)	p-value[‡]	Adjusted results	95% CI difference for adjusted results
TISS score	28.64 (9.87)	32.50 (10.93)	−3.86 (−4.98 to −2.74)	<.001	2.72[§]	1.65 to 3.80	32.33 (11.88)	33.10 (12.69)	−0.77 (−2.10 to 0.57)	.26	1.33[§]	−0.03 to 2.69
ICNSS score	28.76 (4.93)	31.00 (5.22)	−2.24 (−2.80 to −1.68)	<.001	1.63[§]	1.08 to 2.18	32.25 (5.14)	33.36 (5.13)	−1.11 (−1.68 to −0.54)	<.001	1.15[§]	0.56 to 1.73
N/P ratio	0.99 (0.20)	1.01 (0.23)	−0.02 (−0.05 to 0.00)	.043	0.02[§]	−0.00 to 0.05	1.03 (0.28)	1.02 (0.22)	−0.00 (−0.03 to 0.03)	>.80	−0.01[§]	−0.04 to 0.03
N/P ratio < 1	4,442 (56.3)	170 (54.7)		.56	0.91[¶]	0.72 to 1.16	1,289 (78.6)	289 (75.1)		.13	0.87[¶]	0.67 to 1.14
ICNSS index	1.17 (0.25)	1.15 (0.24)	0.01 (−0.2 to 0.04)	.41	−0.01[§]	−0.34 to 0.3	1.15 (0.24)	1.16 (0.24)	−0.01 (−0.03 to 0.02)	.65	0.01[§]	−0.02 to 0.04
ICNSS index > 1	5,897 (74.8)	225 (72.3)		.32	0.91[¶]	0.69 to 1.19	1,489 (90.8)	336 (87.3)		.046	0.74[¶]	0.52 to 1.06

Abbreviations: CI, confidence interval; ICNSS, Intensive Care Nursing Scoring System; MOF, Multiple organ failure; N/P ratio, nurse-to-patient ratio; TISS, Therapeutic Intervention Scoring System.

[†]Data are presented using frequencies and percentages as well as means and standard deviations.

[‡]An Independent-Samples t-Test was applied for comparison of the continuous variables. In addition, Fisher exact test was used to compare categorical variables.

[§]Difference.

[¶]Odds ratio.

TABLE 5 The level of nursing workload and nurse staffing prior MOF between survivors and non-survivors

Variable†	MOF within 48 hr (N = 1735)						MOF > 48 hr after ICU admission (N = 291)					
	Survivor (N = 1,407)	Non-survivor (N = 328)	Difference (95% CI)	p-value‡	Adjusted results	95% CI difference for adjusted results	Survivor (N = 234)	Non-survivor (N = 57)	Difference (95% CI)	p-value‡	Adjusted results	95% CI difference for adjusted results
TISS score	30.51 (11.33)	31.16 (12.12)	−0.65 (−2.0 to 0.73)	.36	0.85§	−0.56 to 2.27	43.32 (8.78)	44.28 (9.87)	1.33 (−3.58 to 1.66)	.47	1.06§	−1.67 to 3.79 c
ICNSS score	31.68 (5.03)	32.83 (5.02)	−1.15 (−1.75 to −0.54)	<.001	1.01§	0.39 to 1.64	35.68 (4.49)	36.42 (4.68)	−0.74 (−2.06 to 0.57)	.27	0.94§	−0.43 to 2.31 c
N/P ratio	1.05 (0.29)	1.04 (0.22)	0.07 (−0.03 to 0.04)	.66	−0.01 §	−0.04 to 0.03	0.90 (0.17)	0.93 (0.15)	−0.03 (−0.08 to 0.021)	.26	0.04§	−0.01 to 0.09 c
N/P ratio < 1	1,077 (76.6)	242 (73.8)		.28	0.91¶	0.68 to 1.21	212 (90.6)	47 (82.5)		.10	0.41¶	0.16 to 1.03
ICNSS index	1.13 (023)	1.14 (0.24)	−0.01 (−0.04 to 0.02)	.42	0.01§	−0.02 to 0.04	1.28 (0.26)	1.25 (0.21)	0.03 (−0.04 to 0.10)	.42	−0.04§	−0.11 to 0.04 c
ICNSS index > 1	1,265 (90.0)	284 (86.6)		.09	0.76¶	0.53 to 1.11	224 (95.7)	52 (91.2)		.18	0.42¶	0.12 to 1.46

Abbreviations: CI, confidence interval; ICNSS, Intensive Care Nursing Scoring System; MOF, Multiple organ failure; N/P ratio, nurse-to-patient ratio; TISS, Therapeutic Intervention Scoring System.

†Data are presented using frequencies and percentages as well as means and standard deviations.

‡An Independent-Samples t-Test was applied for comparison of the continuous variables. In addition, Fisher exact test was used to compare categorical variables.

§Difference.

¶Odds ratio.

should be developed to facilitate the prediction of nurse staffing requirements.

5.1 | Strengths and limitations of the study

To the best of our knowledge, this is only the second study measuring nurse staffing through the use of both N/P ratio and ICNSS index (Jansson et al., 2019). In contrast to the previous literature, the nursing staff requirement was systematically analysed in this study by using two different scores, which yielded equal results with a sufficient sample size.

Nevertheless, our study has several limitations. Firstly, this was a single-centre, hospital-based, cross-sectional study, which may limit the generalizability of our results. In this population, the mean age of patients was higher than in general in the Finnish population (42.3 years old in 2015). The mean age of patients was somewhat younger than the age in previously published articles (Dimick et al., 2001; Hugonnet, Chervolet, et al., 2007; Hugonnet, Uckay, et al., 2007; Lee et al., 2017); however, the mean age was in harmony with previous studies (Daud-Gallotti et al., 2012; Needleman et al., 2011; Neuraz et al., 2015). In addition, the severity of illness was slightly lower than that reported in other studies (Daud-Gallotti et al., 2012; Hugonnet, Chervolet, et al., 2007; Hugonnet, Uckay, et al., 2007; Lee et al., 2017; Neuraz et al., 2015).

In addition, the validity of documentation was not controlled by external monitoring as is the case in prospective trials. Secondly, due to a lack of data, we did not examine the association between adverse patient outcomes and the educational and/or training level of nurses, nor did we consider the bundle compliance and other confounding factors, such as the contribution of medical staff and other personnel or the presence of students and trainees, all of which may have had an impact on nursing efficacy and workload. Finally, both the clinical treatment of patients and research was conducted by the same clinicians. The data, were, however, analysed by a blinded researcher and biostatistician to reduce the risk of potential bias.

6 | CONCLUSION

In conclusion, the proportion of understaffing and increased nursing workload are associated with multiple organ failure, demonstrating that an adequate level of nurse staffing in relation to patient complexity is a prerequisite for the availability and quality of critical care services. The proportion of understaffing, however, did not differ between survivors and non-survivors.

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CONFLICT OF INTEREST

No conflict of interest has been declared by the authors.

AUTHORS' CONTRIBUTIONS

All authors have agreed on the final version and meet at least one of the following criteria (recommended by the ICMJE*): (1) substantial contributions to conception and design, acquisition of data and analysis and interpretation of data; (2) drafting the article or revising it critically for important intellectual content.

ORCID

Miia Jansson https://orcid.org/0000-0001-5815-0325

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