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Association between organizational characteristics and adequate pain management at the intensive care unit

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Conflicts of interest

None

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Keywords: pain, intensive care units, organizational characteristics, nurse to patient ratio, bed occupancy rate, intensivist presence.

Abbreviations Fte = full-time equivalent; NICE = national intensive care evaluation; VAS = Visual Analog Scale; NRS = Numeric Rating Scale; BPS = Behavioral Pain Scale; CPOT = Critical-Care Pain Observation Tool; EHR = Electronic Health Record; CPOE = computerized provider order entry

Abstract

Purpose Half of the patients experience pain during their ICU stay which is known to influence their outcomes. Nurses and physicians encounter organizational barriers towards pain assessment and treatment. We aimed to evaluate the association between adequate pain management and nurse to patient ratio, bed occupancy rate, and fulltime presence of an intensivist.

Materials and Methods We performed unadjusted and case-mix adjusted mixed-effect logistic regression modeling on data from thirteen Dutch ICUs to investigate the association between ICU organizational characteristics and adequate pain management, i.e. patient-shift observations in which patients' pain was measured and acceptable, or unacceptable and normalized within 1 hour.

All ICU patients admitted between December 2017 and June 2018 were included, excluding patients who were delirious, comatose or had a Glasgow coma score < 8 at the first day of ICU admission.

Results Case-mix adjusted nurse to patient ratios of 0.70 to 0.80 and over 0.80 were significantly associated with adequate pain management (OR [95% confidence interval] of respectively 1.14 [1.07 – 1.21] and 1.16 [1.08 – 1.24]). Bed occupancy rate and intensivist presence showed no association.

Conclusion Higher nurse to patient ratios increase the percentage of patients with adequate pain management especially in medical and mechanically ventilated patients.

Introduction

Pain experienced during ICU stay is a major issue and known to influence patient outcomes. Pain decreases comfort and sleep and increases morbidity, mortality and length of stay [1-3]. During their stay half of the ICU patients experience moderate to severe pain [4-6]. Pain increases during procedures such as turning, chest tube removal, wound drain removal, and arterial line insertion. Furthermore pain experienced before a procedure is associated with greater pain during a procedure [6, 7]. The frequent assessment and appropriate treatment of pain is associated with decreased incidence of pain, need for sedatives, duration of mechanical ventilation, ICU and hospital length of stay, and mortality [3, 8, 9]. Therefore, it should be encouraged that pain during ICU admission is optimally managed. However nurses and physicians encounter barriers towards pain assessment and treatment, for example pain is not always easy to measure, especially in mechanically ventilated or sedated patients [10]. Furthermore, qualitative studies investigating health professionals' practices and barriers regarding pain management in ICUs indicated that inadequate staffing levels to meet workload and the need of doctor's approval for prescribing proper pain medication hampered nurses to provide adequate pain management [11-13]. In addition, studies that described pain experience of ICU patients showed that most patients waited for the nurse to ask them about their pain before communicating its presence [14]. Therefore, it can be hypothesized that a lower nurse to patient ratio, higher bed occupancy rate, and a reduced presence of intensivists are associated with less patients receiving adequate pain management. To our knowledge no studies have quantitatively investigated the association between these ICU organizational characteristics and pain management before. Within this multicenter study we aim to gain more insight into the organizational characteristics associated with adequate pain management in Dutch ICU patients during their admission.

Materials and Methods

Data collection

In the Netherlands, the National Intensive Care Evaluation (NICE) registry, enables ICUs to monitor and improve their quality of care. The NICE registry provides all 83 Dutch ICUs with audit and feedback

(A&F) information on patient outcomes such as mortality and length of stay, and optional on topics such as organizational characteristics, complications, sepsis and sequential organ failure [15]. In 2017, the NICE registry developed and implemented a web based module with four actionable quality indicators in order to improve quality of pain management [16]. The data needed to calculate the pain indicators consist of date and time of pain assessment, pain score, and type of assessment tool [17]. Pain measurements were performed in patients at rest, usually by nurses, but also by physicians, and measured with validated measurement instruments. The Visual Analog Scale (VAS) or the Numeric Rating Scale (NRS) was used in patients able to self-report pain and the Behavioral Pain Scale (BPS) or Critical-Care Pain Observation Tool (CPOT) in patients not able to self-report, e.g. sedated or mechanically ventilated patients [8, 18, 19].

We used data from thirteen (15.7%) mixed medical-surgical ICUs that voluntarily engaged in the pain management module of the NICE registry and for which data on organizational characteristics and pain management was available for all patients admitted between December 2017 and June 2018. The ICUs extracted these data from their electronic health record (EHR) in addition to their regular uploaded NICE data on patient demographics, physiological and diagnostic data such as comorbidities and reason of admission [15]. Patients who were not delirious or comatose and had a Glasgow coma score ≥ 8 at the first day of ICU admission were eligible for inclusion, because the pain instruments are only validated for these patients [20].

Outcome measure

Our outcome measure was the proportion of ICU patients per shift with adequate pain management. Our unit of observation is a patient shift as the availability of nurses and intensivists, and bed occupancy rate change over shifts. Adequate pain management for a patient during a shift (day, evening or night shift) was defined as 'yes (1)' when at least one pain measurement was performed during that shift and all measurements performed had acceptable pain scores OR in case of an unacceptable pain score the pain was re-measured and normalized within 1 hour [16, 21]. A pain measurement had an unacceptable score when VAS/NRS>3, CPOT>2 and BPS>5 [8, 18, 19]. We

excluded the first shift of patients' ICU admission because presence of pain is not in control of the ICU when patients from the operating room or from the emergency room arrive at the ICU with high pain scores.

Organizational determinants of adequate pain management

Based on literature, expert opinion and the availability of data in the NICE registry we explored the impact of four potential organizational determinants of adequate pain management: nurse to patient ratio, bed occupancy rate, intensivist presence (hours) during workdays and intensivist presence (hours) during weekends. Nurse to patient ratio was determined by dividing the number of full-time equivalent (Fte) ICU certified nurses during a shift by the maximum number of patients present at the ICU during that shift. Bed occupancy rate was determined by dividing the maximum number of patients present at the ICU during a shift by the number of available ICU beds during that shift, multiplied by 100.

Data analysis

We performed unadjusted – i.e. univariate and case-mix adjusted – i.e. multivariate mixed-effect logistic regression modeling to investigate the association between each of the four organizational characteristics and adequate pain management. Nurse to patient ratio and bed occupancy rate were included in the models as quintiles and intensivist presence during workdays and weekends as dichotomous variables (less than 24 hour vs. full time coverage i.e. 24 hour).

In 2007 Chanques et al. [4] showed that the intensity of NRS scores at rest were higher in ICU medical patients as compared to surgical-trauma patients. Other factors that have been shown to be associated with higher pain scores in ICU patients are a young age, number of comorbidities, colon cancer, and abdominal surgery [22-25]. Therefore, in each of the multivariate models we adjusted the effect of the organizational characteristic for age, gender, admission type (medical vs. surgical) and Acute Physiology and Chronic Health Evaluation (APACHE) IV mortality probability. We included APACHE IV mortality probability as an overall measure for severity of illness as it includes the combined

information on comorbidities, physiological disturbance, and admission diagnosis and because the limited number of included ICUs (n=13) requires a strict policy on the number of covariates in the model. Age and APACHE IV mortality probability were included in the model as restricted cubic splines to allow a non-linear relationship with adequate pain.

We included a random intercept for 'ICU' and for 'patient admission' to account for clustering effects of observations within ICUs and for repeated measurements within patients. We tested with ANOVA whether the model including a specific organizational characteristic improved compared to a model with only the case-mix variables and random intercepts for 'ICU' and 'patient' included. We defined improvement as a p-value smaller than 0.05.

As post-hoc analysis we repeated the multivariate analyses that resulted in a significant association for subgroups medical vs. surgical admissions and for patients mechanically ventilated in the first 24 hour vs. not mechanically ventilated in the first 24 hour. Statistical analysis were performed using R version 3.4.3 (R Foundation for Statistical Computing; Vienna, Austria).

Results

Of the thirteen included ICUs six were located in a general hospital, five in a teaching hospital and two in a university affiliated hospital. The median number of ICU beds was 14.0 (interquartile range (IQR); 8.0 – 30.2). Supplementary material 1 shows the flow of patient inclusion. Table 1 shows characteristics of the 8136 included patients together with the percentage of patients per shift with at least one pain measurement. Table 2 describes per organizational characteristic the median and interquartile range (IQR) of the thirteen included ICUs. For all ICUs the presence of intensivists appeared to be equal for weekdays and weekends, therefore this variable was combined in the regression analysis. The percentage of patients with adequate pain management during a specific shift ranged from 57.6% to 84.8% in the thirteen ICUs (Figure 1).

Table 3 presents the unadjusted and adjusted odds ratios for the associations between the organizational determinants and adequate pain management. The unadjusted nurse to patient ratio of 0.55 or higher was significantly associated with a higher percentage of patients with adequate pain

management as compared to a nurse to patient ratio of 0.55 or less. This association remained significant for the nurse to patient ratios of 0.70 to 0.80 and over 0.80 after case-mix adjustment. Adding nurse to patient ratio to the model that only included the case-mix variables and random intercepts improved the model significantly (ANOVA $p<0.001$). Bed occupancy rate and intensivist presence were unadjusted and adjusted not associated with adequate pain management and did not improve the model that only included the case-mix variables and random intercepts.

The post-hoc analysis (Table 4) showed that a case-mix adjusted nurse to patient ratio of 0.63 or higher was significantly associated with a higher percentage of patients with adequate pain management in medical and mechanically ventilated patients. For surgical and non-mechanically ventilated patients we found no association.

Discussion

We examined the association between four ICU organizational characteristics and adequate pain management. This study shows that nurse to patient ratio is significantly associated with adequate pain management in Dutch ICUs especially in medical and mechanically ventilated patients. For bed occupancy rate and presence of intensivists we did not find an association with adequate pain management.

Our finding that a higher nurse to patient ratio increases the percentage of patients with adequate pain management per shift confirms the results from earlier mostly qualitative studies in which ICU nurses indicated that a lack of manpower and time withheld them from adequate pain management [11, 12, 26]. However, this does not necessarily mean that patients admitted to an ICU with lower nurse to patients ratios experience more pain. An alternative explanation for our finding is that pain is treated appropriate at all ICUs, but ICUs with a higher nurse to patient ratio may have more time to record the normalized pain score into the EHR. However, complete registration is part of adequate pain management to avoid excessive use or side effects of pain medication due to missing normalized pain scores [27]. Our hypothesis was that a high bed occupancy rate would be associated with a decreased percentage of patients with adequate pain management during a shift. However, bed

occupancy rate did not show to be associated with adequate pain management. A possible explanation is the fact that the bed occupancy rate does not account for patient turnover. Patient turnover is a factor within the ICU work environment that disrupts workflows associated with the nursing process resulting in increased nursing workload. Consequently, when the time cost of patient turnover exceeds the time available within a nurse's schedule this might result in less adequate pain management [28]. However, when the increased need for nursing care can be accommodated by an increase in nursing staff, patient turnover is not a problem. We hypothesized that presence of intensivists was associated with adequate pain management as physicians prescribe pain medication which thereafter can be administered by the ICU nurses. The absence of an association between intensivist presence and adequate pain management might be explained by the availability of nurse-driven protocols. All included ICUs mentioned they had a pain protocol, but unfortunately we do not have any data in our dataset on whether this were nurse-driven protocols. A nurse-driven protocol enables ICU nurses to make decisions on their own e.g. about administering pain medication, without or with less consultation of the attending intensivist [29, 30]. Another explanation might be the use of computerized provider order entry (CPOE) as these systems can improve pain control by reducing medication prescription errors or initiation of prompts should a intensivist fail to order pain medication for a patient who reports pain [31].

A strength of this study is that we performed multicenter analysis and we believe that our results are likely to be generalizable to other ICUs with similar organizational factors. Next, by analyzing the association of nurse to patient ratio and bed occupancy rate with adequate pain management per shift we took into account that these factors can differ per shift. A limitation of this study might be that selection bias has occurred because ICUs participated on a voluntarily basis. The ICUs that participated are more likely to have their pain management practice and organization well-arranged than those that did not participate. Another possible limitation is that we did not have information on measures that directly influence the process of pain management such as the availability of decision support in the electronic health record of the ICUs that prompt to measure or re-measure pain, or to evaluate

the pain medication. Decision support may improve pain management [32, 33], but it can also result in alert fatigue – i.e. health professionals ignoring the prompts [34]. Furthermore, the effectiveness of the prompts also depends on the quality of it. Future research on this type and other organizational characteristics might further unravel how ICUs might improve pain management.

Conclusion

We found a positive association between nurse to patient ratio and adequate pain management especially in medical and mechanically ventilated patients. This finding confirms the believes of nurses that a lack of manpower withheld them from adequate pain management and underpins the importance of sufficient nurse staffing levels.

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Tables

Figures

Supplementary material

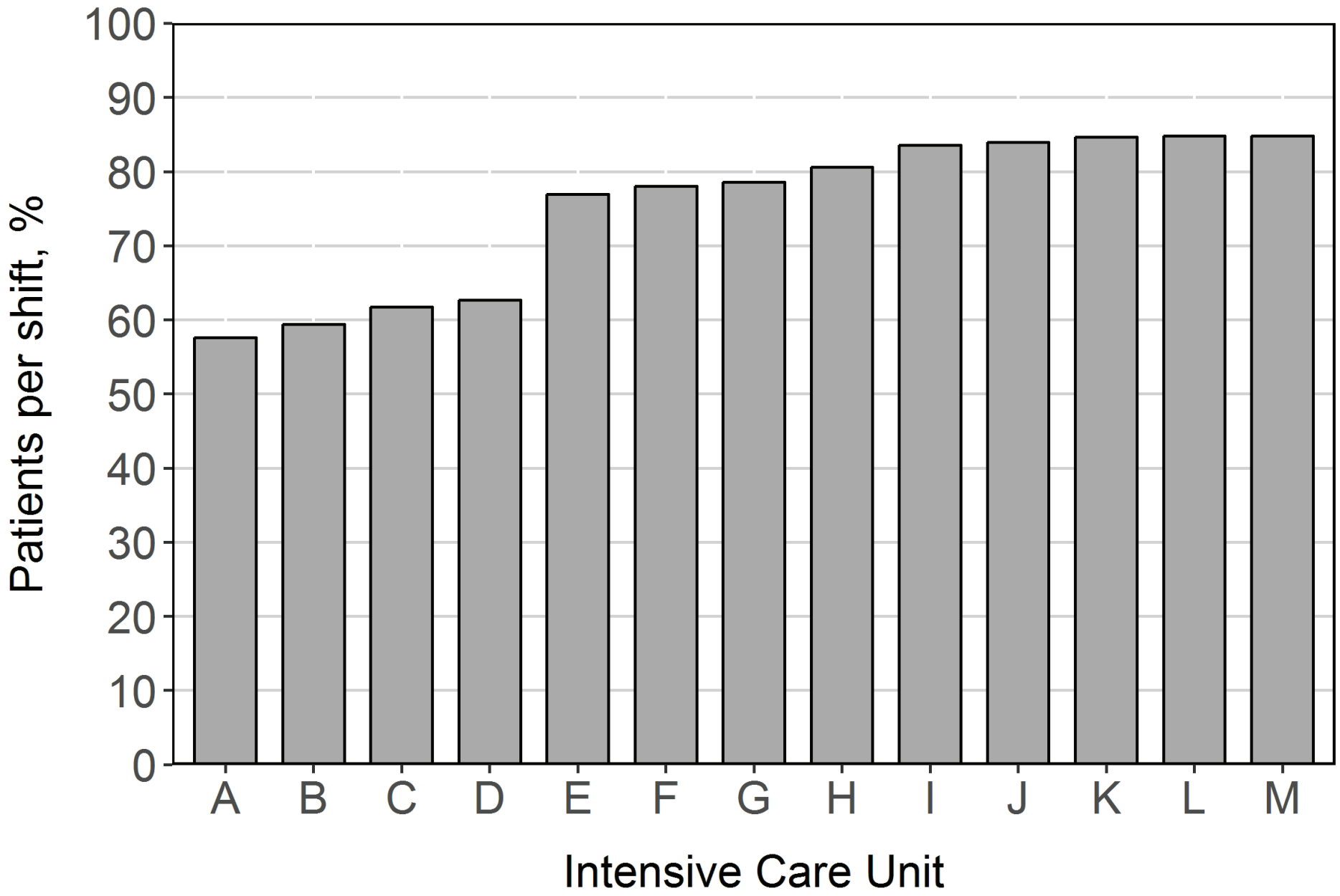

100
90
80
70
60
50
40
30
20
10
0
Patients per shift, %
A
B
C
D
E
F
G
H
I
J
K
L
M
Intensive Care Unit

Table 1 Description of patient characteristics ~~included in the model~~ of the 13 included intensive care units

Patient characteristic	~~n=8136~~Admission count (%)	Patient-shifts with at least one pain measurement, %
ICU admissions	8136	81.2 (65565/80743)
Gender male~~, n (%)~~	5140 (63.2)	81.1 (42940/52971)
Admission type~~, n (%)~~		
Medical	3714 (45.6)	79.8 (40745/51068)
Surgical	4422 (54.4)	83.6 (24820/29675)
Mechanical ventilation first 24 h	4497 (55.3)	80.7 (44527/55170)
	Median (IQR)	
Age in years~~, median (IQR)~~[a]	67.0 (57.0 – 74.0)	
	Mean (SD)	
APACHE IV mortality probability~~, mean (SD)~~[a]	0.17 (0.23)	

[a]Presented as median with interquartile range (IQR) or mean and standard deviation (SD), but included as splines in the regression analysis

Table 2 ~~Description of the analyzed organizational c~~Characteristics of the 13 included intensive care units

Organizational characteristic	n=13
Number of admissions mechanically ventilated in first 24 h[a]	182 (59 – 651)
Nurse~~s~~ to patient ratio, average per shift[a]	0.75 (0.68 – 0.84)
Bed occupancy rate, average % per shift[a]	73.9 (67.8 – 84.1)
Intensivist presence (hours)	
Working days, n (%)	
< 24.0	6 (46.2)
24.0	7 (53.8)
Weekends, n (%)	
< 24.0	6 (46.2)
24.0	7 (53.8)

[a]Presented as median (interquartile range; IQR)

Table 3 Odds ratios (ORs) for adequate pain management of unadjusted and case-mix adjusted analyses

Organizational characteristic	OR (95% CI)	p-value	Adjusted[a] OR (95% CI)	p-value
Nurse to patient ratio				
Up to 0.55	Reference		Reference	
0.55 to 0.63	1.06 (1.00 – 1.12)	0.047	1.06 (1.00 – 1.12)	0.05
0.63 to 0.70	1.07 (1.00 – 1.14)	0.04	1.06 (1.00 – 1.13)	0.06
0.70 to 0.80	1.14 (1.07 – 1.22)	<0.001	1.14 (1.07 – 1.21)	<0.001
Over 0.80	1.17 (1.09 – 1.25)	<0.001	1.16 (1.08 – 1.24)	<0.001
Bed occupancy rate				
Up to 69.0	Reference		Reference	
69.0 to 80.0	1.01 (0.95 – 1.08)	0.77	1.01 (0.95 – 1.08)	0.68
80.0 to 88.2	1.03 (0.96 – 1.11)	0.34	1.04 (0.97 – 1.11)	0.29
88.2 to 96.3	1.01 (0.94 – 1.09)	0.72	1.02 (0.94 – 1.09)	0.67
Over 96.3	1.02 (0.95 – 1.10)	0.53	1.02 (0.95 – 1.10)	0.53
Intensivist presence (hours)[b]				
< 24.0	Reference		Reference	
24.0	0.88 (0.41 – 1.88)	0.74	0.94 (0.43 – 2.08)	0.88

[a]Adjusted for the case-mix variables gender, age, admission type (medical or surgical), and Acute Physiology and Chronic Health Evaluation (APACHE) IV mortality probability.

[b]The results for working days and weekends are presented together because ICUs with an intensivist present 24 hours per day during working days had this also during weekends.

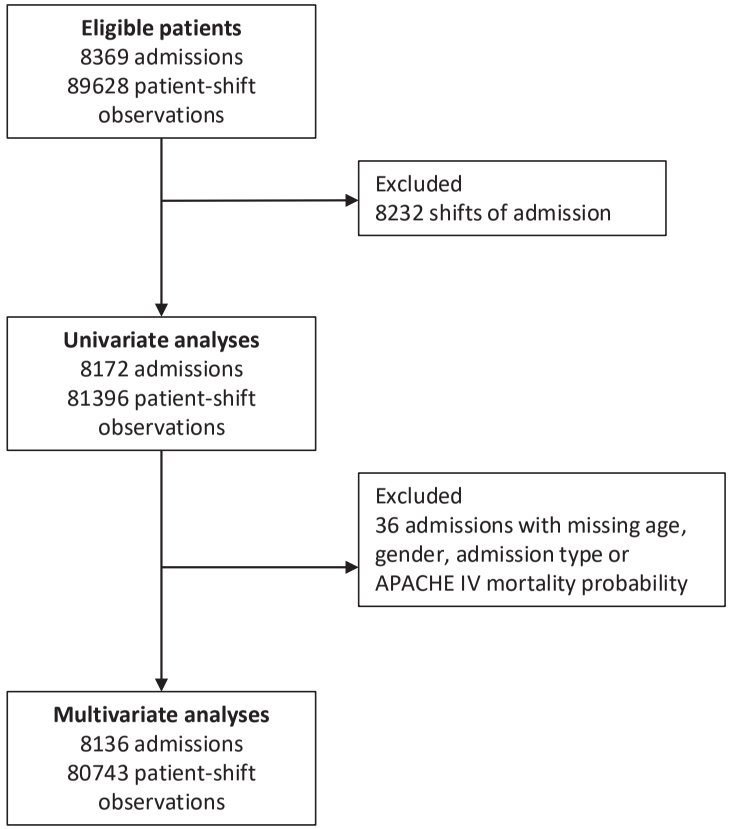
Table 4 Odds ratios (ORs) for adequate pain management of j asecmi- adxusted analyses Uit0in medij al . s5surgij al and mej 0anij ally . entilated . s5nonc mej 0anij ally . entilated patients

	Medical admission		Surgical admission		Mechanically ventilated		Non-mechanically ventilated	
Organizational characteristic	**Adjusted[a] OR (95% CI)**	**p-value**	**Adjusted[a] OR (95% CI)**	**p-value**	**Adjusted[b] OR (95% CI)**	**p-value**	**Adjusted[b] OR (95% CI)**	**p-value**
Nurse to patient ratio								
6p to 3577	Referenj e		Referenj e		Referenj e		Referenj e	
3577 to 358v	1537 (3542 9 1510v)	3514	1532 (3542 9 1512)	351<	1538 (3544 9 1510h)	3532	1538 (3547 9 1512)	35<2
358v to 35-3	1513 (1531 9 1514)	353<	1531 (3541 9 1510<)	352v	1532 (1533 9 1518)	3537	153h (354< 9 1510–)	357<
35-3 to 3523	15<3 (1511 9 15v3)	b35331	153h (354h 9 1517)	35h–	1518 (153– 9 15<7)	b35331	1513 (3544 9 15<h)	3534
O. er 3523	15<7 (1510h 9 15v7)	b35331	1531 (3541 9 1510<)	3522	15<< (1510v 9 15vv)	b35331	153h (354v 9 1510–)	35h4

[a]Adxusted for t0e j asecmi- . aria, les genderPage and Aj ute C0ysiology and H0ronij Eealt0 I . aluation (ACAHEI) VT mortality pro, a, ility5

[b]Adxusted for t0e j asecmi- . aria, les genderPagePadmission type (medij al or surgij al)Pand Aj ute C0ysiology and H0ronij Eealt0 I . aluation (ACAHEI) VT mortality pro, a, ility5

[b]w0e results for Uorking days and Ueekends are presented toget0er , ej ause VH6 s Uit0 an intensi. ist present <h 0ours per day during Uorking days 0ad t0is also during Ueekends5


Eligible patients
8369 admissions
89628 patient-shift observations
Excluded
8232 shifts of admission
Univariate analyses
8172 admissions
81396 patient-shift observations
Excluded
36 admissions with missing age, gender, admission type or APACHE IV mortality probability
Multivariate analyses
8136 admissions
80743 patient-shift observations