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The Nursing Activities Score Per Nurse Ratio Is Associated With In-Hospital Mortality, Whereas the Patients Per Nurse Ratio Is Not*

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Objectives: Studies have shown contradicting results on the association of nursing workload and mortality. Most of these studies expressed workload as patients per nurse ratios; however, this does not take into account that some patients require more nursing time than others. Nursing time can be quantified by tools like the Nursing Activities Score. We investigated the association of the Nursing Activities Score per nurse ratio, respectively, the patients per nurse ratio with in-hospital mortality in ICUs.
Design: Retrospective analysis of the National Intensive Care Evaluation database.
Setting: Fifteen Dutch ICUs.
Patients: All ICU patients admitted to and registered ICU nurses working at 15 Dutch ICUs between January 1, 2016, and January 1, 2018, were included. The association of mean or day 1 patients per nurse ratio and Nursing Activities Score per nurse ratio with in-hospital mortality was analyzed using logistic regression models.
Interventions: None.
Measurements and Main Results: Nursing Activities Score per nurse ratio greater than 41 for both mean Nursing Activities Score per nurse ratio as well as Nursing Activities Score per nurse ratio on day 1 were associated with a higher in-hospital mortality (odds ratios, 1.19 and 1.17, respectively). After case-mix adjustment the association between a Nursing Activities Score per nurse ratio greater than 61 for both mean Nursing Activities Score per nurse ratio as well as Nursing Activities Score per nurse ratio on day 1 and in-hospital mortality remained significant (odds ratios, 1.29 and 1.26, respectively). Patients per nurse ratio was not associated with in-hospital mortality.
Conclusions: A higher Nursing Activities Score per nurse ratio was associated with higher in-hospital mortality. In contrast, no association was found between patients per nurse ratios and in-hospital mortality in The Netherlands. Therefore, we conclude that it is more important to focus on the nursing workload that the patients generate rather than on the number of patients the nurse has to take care of in the ICU. (*Crit Care Med* 2020; 48:3–9)
Key Words: in-hospital mortality; intensive care; nurse-to-patient-ratio; Nursing Activities Score-to-nurse ratio; nursing activity score; nursing workload

Critically ill patients in ICUs require intensive nursing care and monitoring (1). This is one of the main reasons why ICU care is expensive. In Europe, the costs of ICUs represent approximately 20% of total hospital costs (2). On average, 50% of the budget of the ICU is spend on nursing staff (3). Hence, taking a critical evaluation on how many nurses are actually needed is of great importance from an economical point of view. On the other hand, reducing the number of nurses working at the ICU due to budgetary cuts will increase nursing workload which may have a negative

*See also p. 126.

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impact on patient safety and thereby patients' mortality risk. Additionally, reduction of the number of nurses can negatively impact nurses well-being (4). Therefore, quantification of an optimal patient to nurse ratio (PNR) has been a topic of debate for years (5).

In a meta-analysis conducted by Numata et al (6) a positive relationship between higher nurse staffing levels and lower in-hospital mortality among critical care patients was found, but after additional case-mix adjustment, the reported association became nonsignificant in four out of five included studies. A recent meta-analysis in ICUs found that higher PNRs are associated with a 14% increase in the in-hospital mortality risk (7). In these studies, the fact that patients differ in their need for nursing care is neglected. This makes it difficult to compare studies in which nurses take care of different type of patients, thereby hampering meta-analyses. A recent editorial suggests that nurse staffing levels should reflect a combination of patient nursing need (acuity and dependency level), patient throughput, nursing competency, and availability of ancillary staff (8).

The Nursing Activities Score (NAS) is a well known and frequently used scoring system to quantify the need of nursing care in ICUs (9). This scoring system assigns a score per patient based on the executed nursing tasks, where each of them is weighted for the time spent per task. The scores are translated to full-time equivalent (FTE), where 100 points equals 1 nursing FTE. The score per patient can run from 0 to 170 points. So one nurse can take care of several patients, whereas some patients need to be taken care of by more than one nurse. To date, the NAS is the most commonly used instrument to measure nursing workload in ICUs. The NAS was validated with Multi Moment Recordings, where they showed that 81% of the total time spent by nurses was explained by the NAS (9). Furthermore, Stafseth et al (10) performed a study on the validity and reliability of the NAS and provided empirical support for its usefulness in the assessment of critical care nursing. The NAS per nurse ratio (NNR) represents the amount of workload per nurse executed per shift and may be a more reliable measure of workload than the PNR. Although the PNR does not consider the amount of workload that a patient requires, the NNR provides more elaborate information on the workload, since it takes into account the amount of time a nurse spends on a patient and is therefore more likely to be an efficient measure for capturing the workload of a nurse. However, to our knowledge, no studies have been published using the NNR to assess the association of workload with in-hospital mortality.

Therefore, the aim of this study was to investigate the association of nursing workload, expressed as NNRs and in-hospital mortality and to compare this with the association of PNR and in-hospital mortality in ICUs.

MATERIALS AND METHODS

Setting

We used data from the Dutch National Intensive Care Evaluation (NICE) quality registry in which all Dutch ICUs participate since 2016 (11). The NICE minimal dataset consists of demographic, physiologic and diagnostic data, and in-hospital mortality of all admitted ICU patients in all Dutch hospitals. One of the optional modules in the NICE registry is the nursing workload module in which ICUs register per shift, among others, the present number of FTE nurses and all data items needed to calculate the NAS per patient per shift (12).

Data Collection

For this study, we performed a retrospective analysis of the NICE database. We included all ICU admissions between January 1, 2016, the start of the NAS data collection within the NICE registry, and January 1, 2018, from all 15 Dutch ICUs (out of 82 ICUs in The Netherlands) that voluntarily participated in the nursing workload module. We excluded patients that were readmitted during the same hospitalization period and patients that were admitted for less than 1 day. Almost all needed data for the nursing workload module (around 90%) can be automatically extracted from the electronic health record (EHR), but in some hospitals, the nurses have to manually register the data at the end of their shift into a specific form in the EHR. When nurses need to manually register the data, they are trained for this by following an e-learning on the nursing workload module of the NICE registry.

Ethical Approval

The Institutional Research Board of the Amsterdam University Medical Center reviewed the research proposal and waived the need for informed consent (Institutional Review Board protocol W17_366).

Calculation of NNRs and PNRs

NAS was developed to use for a 24 hours period but can also be used per shift as was done in the included ICUs. For the calculation of the daily NNRs, the number of assigned NAS points for each nursing intervention per shift has been converted into points at daily level per nursing intervention according to the original NAS model. For example, with the nursing intervention "drains," the maximum scored value over three shifts was taken, for the nursing intervention "bedside" the hours of the three shifts were summed. Finally, all these daily NAS points for the different nursing interventions were summed to reach the NAS score per day. Subsequently, the sum of the daily NAS score of all patients during a day were divided by the average number of registered ICU nurses present (excluding student or other types of nurses) during that day to assess the daily NNRs.

For the calculation of the daily PNRs, we converted the data collected per shift into a daily score. First, the PNRs of the day, evening, and night shifts were calculated by dividing the number of ICU patients (recovery unit and coronary care unit patients were excluded) present during the shift by the number of registered ICU nurses (student- and non-registered ICU nurses were excluded) present. Subsequently, the average of the PNRs of the day, evening, and night shift per day were used as daily PNRs. For the definitions of the NNR and PNR, see **Table S1** (http://links.lww.com/CCM/E934).

As a sensitivity analysis, we also performed the NNRs and PNRs analysis including the recovery unit and coronary care unit patients admitted to the ICU and including the student nonregistered ICU nurses to check whether these changes in definition influenced the results.

Statistical Analysis

Categorical variables were presented using absolute and relative frequencies, and the continuous variables were presented using mean with SDs or median with interquartile ranges depending on their distribution. Patients with missing NAS values were excluded from the analysis.

Multilevel logistic regression modeling was used with in-hospital mortality as a dependent variable and hospital of admission as a random intercept to correct for clustering within hospitals (**Table 1**). The independent variables were either NNR or PNR on day 1 of admission; or mean NNR or PNR of the patients' whole ICU admission in accordance to previous studies (13, 14). NNRs and PNRs were included as categories based on quartiles to improve interpretation. PNRs and NNRs were included as categories based on quartiles to improve interpretation. These quartiles were created based on the range of the data in our own study. The association between the NNR/PNR and the in-hospital mortality were investigated in eight separate models; four without case-mix adjustment and four with case-mix adjustment (Table 1). In the models with case-mix adjustment, we included patient characteristics that did not change during the entire ICU admission, namely the chronic comorbidities that are present before hospital admission, type of admission (medical, urgent, or elective surgery), and age of the patients. The chronic comorbidities included immunological insufficiency, neoplasm, hematologic malignancy, cirrhosis, chronic cardiovascular insufficiency, chronic renal insufficiency, chronic dialysis, chronic obstructive pulmonary disease, and chronic respiratory insufficiency. These data were extracted from the mandatory minimal dataset module of the NICE and thus did not lead to extra registration burden for the nurses.

The odds ratio (OR) with 95% CI for the variables NNR and PNR were calculated and a CI not containing one was considered as statistical significant. All statistical analyses were performed using R studio (version 1.0.136; R Project for Statistical Computing, Vienna, Austria) using the R language (version 3.3.3, R Project for Statistical Computing).

RESULTS

Baseline Results

The mean number of ICU beds of the included ICUs was slightly lower than ICUs that did not participate in the nursing workload module, although not significant. **Table 2** shows that also the other characteristics of the ICUs are similar. In total, 34,524 patients were admitted for the first time during their hospitalization period to an ICU that participated with the NICE nurse workload module (**Table 3**). For 29,445 patients (85%) workload data was collected and could be included in our study. Because of missing NAS values, 15% of the patients were excluded from the analysis. The demographic characteristics of the included and excluded patients show some small differences of which we presume that they have no influence on our found results, as the in-hospital mortality rate among the excluded patients was similar to that of the included patients (Table 3). Of the 29,445 included patients, 11.8 % died during the hospital admission period. The median NNR on day 1 and the mean NNR during the ICU admission period were also almost similar, respectively, 61.1 and 61.2. The median PNR on day 1 was 1.38 and the PNR during the whole ICU admission period was 1.39.

Model Results

For the NNR on day 1 and the mean NNR during the whole ICU admission period, the unadjusted in-hospital mortality

TABLE 1. Overview of Logistic Regression Models

Model No.	Model Format
1	In-hospital mortality ~ (1|hospital of ICU admission) + PNR day 1
2	In-hospital mortality ~ (1|hospital of ICU admission) + PNR day 1 + comorbidities[a] + age + admission type[b]
3	In-hospital mortality ~ (1|hospital of ICU admission) + mean PNR during admission
4	In-hospital mortality ~ (1|hospital of ICU admission) + mean PNR during admission + comorbidities[a] + age + admission type[b]
5	In-hospital mortality ~ (1|hospital of ICU admission) + NNR day 1
6	In-hospital mortality ~ (1|hospital of ICU admission) + NNR day 1 + comorbidities[a] + age + admission type[b]
7	In-hospital mortality ~ (1|hospital of ICU admission) + mean NNR during admission
8	In-hospital mortality ~ (1|hospital of ICU admission) + mean NNR during admission + comorbidities[a] + age + admission type[b]

NNR = Nursing Activities Score per nurse ratio, PNR = patients per nurse ratio.

[a]Comorbidities include immunological insufficiency, neoplasm, hematologic malignancy, chronic cardiovascular insufficiency, chronic dialysis, cirrhosis, chronic renal insufficiency, chronic obstructive pulmonary disease, and chronic respiratory insufficiency.

[b]Values for admission type: medical, urgent surgery, or elective surgery.

TABLE 2. ICU Characteristics

Characteristics	Included ICUs (n = 15)	All Dutch ICUs (n = 82)
Number of university hospitals (%)	2 (13)	8 (10)
Number of teaching hospitals (%)	3 (20)	22 (27)
Number of nonteaching hospitals (%)	10 (67)	52 (63)
Median number of ICU beds per ICU (IQR)	9.0 (7.0–17.0)	12.0 (8.0–16.0)
Median number of registered ICU nurses working at the ICU (IQR)	38.0 (21.5–62.8)	38.3 (21.8–57.9)
Median number of ICU student nurses working at the ICU (IQR)	3.9 (2.3–6.0)	4.0 (2.3–7.1)

IQR = interquartile range.

TABLE 3. Patient Characteristics

Characteristics	Patients With Workload Information	Patients Without Workload Information	p
Number of patients, n	29,445	5,079	–
Age, median (IQR)	66.0 (55.0–74.0)	65.0 (53.0–74.0)	< 0.001
Admission type, n (%)			0.104
Medical	11,977 (41.0)	2,616 (51.6)	–
Surgical: urgent	3,652 (12.5)	578 (11.4)	–
Surgical: elective	13,541 (46.4)	1,876 (37.0)	–
In-hospital mortality, n (%)	3,462 (11.8)	589 (11.8)	0.897
ICU LOS (d), median (IQR)	1.00 (0.80–2.68)	1.11 (0.76–2.02)	< 0.001
LOS prior to ICU admission, median (IQR)	1.56 (0.79–2.61)	1.12 (0.63–1.71)	< 0.001
Comorbidities, n (%)			
Acute renal failure	2,085 (7.1)	354 (7.0)	0.603
Cardiovascular insufficiency	1,350 (4.6)	68 (1.3)	< 0.001
Chronic dialysis	298 (1.0)	113 (2.2)	< 0.001
Chronic renal insufficiency	1,700 (5.8)	405 (8.0)	< 0.001
Chronic respiratory insufficiency	1,120 (3.8)	242 (4.8)	0.006
Cirrhosis	295 (1.0)	92 (1.8)	< 0.001
Chronic obstructive pulmonary disease	3,493 (11.9)	624 (12.3)	0.815
Diabetes	4,975 (16.9)	896 (17.6)	0.288
Gastrointestinal bleeding	434 (1.5)	85 (1.7)	0.582
Hematologic malignancy	489 (1.7)	128 (2.5)	0.001
Immunological insufficiency	2,868 (9.8)	239 (4.7)	< 0.001
Neoplasm	1,902 (6.5)	157 (3.1)	< 0.001
NNR and PNR[a], median (IQR)			
NNR on day 1	61.1 (41.2–77.2)	–	–
NNR mean[b]	61.2 (41.2–76.3)	–	–
PNR on day 1	1.38 (0.96–1.93)	–	–
PNR mean[b]	1.39 (0.97–1.91)	–	–

IQR = interquartile range, LOS = length of stay, NNR = Nursing Activities Score per nurse ratio, PNR = patients per nurse ratio.
[a]PNR and NNR are calculated on only registered ICU nurses and ICU patients.
[b]Calculated over the patients whole ICU LOS.
Dashes indicate there is no added value to show these differences/data is not available.

significantly increased when NNR exceeded 41 NAS points per nurse. After case-mix adjustment, this association remained significant when NNR exceeded 61 NAS points per nurse (**Table 4**). After including all type of nurses and all type of patients at the ICU the unadjusted in-hospital mortality significantly increased just when NNR exceeded 61 NAS points per nurse but after case-mix adjustment results were similar to the analyses with only ICU certified nurses and ICU patients (**Table S2**, Supplemental Digital Content 2, http://links.lww.com/CCM/E935).

For the PNR on day 1 and the mean PNR during the whole ICU admission period, there were no significant associations found before and after case-mix correction (**Table 5**). These findings did not change after including all type of nurses (i.e., student- and non-registered ICU nurses) and all type of patients at the ICU (i.e., ICU as well as recovery unit and coronary care unit patients) as can be seen in **Table S3** (Supplemental Digital Content 3, http://links.lww.com/CCM/E936).

DISCUSSION

A higher workload per patient per nurse, expressed as NNR greater than 61 was related with a higher in-hospital mortality risk in The Netherlands, whereas PNRs are not associated with

TABLE 4. Association Nursing Activities Score per Nurse Ratios and In-Hospital Mortality (*n* = 29,445)

		[a]Model: NNR	[b]Model: NNR + Adjustment
Covariate	Range	OR (95% CI)	OR (95% CI)
NNR day 1	< 41.2	Reference	Reference
	41.2 to < 61.2	1.174 (1.026–1.344)	1.127 (0.972–1.306)
	61.2 to < 76.3	1.295 (1.120–1.496)	1.257 (1.074–1.471)
	≥ 76.3	1.180 (1.014–1.373)	1.180 (1.001–1.390)
Mean NNR	< 41.2	Reference	Reference
	41.2 to < 61.2	1.187 (1.035–1.361)	1.072 (0.922–1.245)
	61.2 to < 76.3	1.433 (1.238–1.660)	1.285 (1.095–1.509)
	≥ 76.3	1.307 (1.120–1.525)	1.237 (1.045–1.462)

NNR = Nursing Activities Score per nurse ratio, OR = odds ratio.
Association models:
[a]Hospital mortality ~ (1|hospital of ICU admission) + NNR.
[b]Hospital mortality ~ (1|hospital of ICU admission) + NNR + comorbidities + age + admission type.
Cell indicating significant result.
NNR calculated including only registered ICU nurses and ICU patients.

TABLE 5. Association Patients per Nurse Ratios and In-Hospital Mortality (*n* = 29,445)

		[a]Model: PNR	[b]Model: PNR + Adjustment
Covariate	Range	OR (95% CI)	OR (95% CI)
PNR day 1	< 0.96	Reference	Reference
	0.96 to < 1.38	1.132 (0.983–1.304)	1.128 (0.996–1.316)
	1.38 to < 1.93	1.057 (0.999–1.475)	1.089 (0.970–1.434)
	≥ 1.93	1.037 (0.852–1.263)	1.109 (0.894–1.376)
Mean PNR	< 0.97	Reference	Reference
	0.97 to < 1.39	1.119 (0.966–1.297)	1.079 (0.918–1.268)
	1.39 to < 1.91	1.032 (0.988–1.573)	1.021 (0.998–1.465)
	≥ 1.91	1.001 (0.789–1.204)	1.034 (0.821–1.304)

OR = odds ratio, PNR = patients per nurse ratio.
Association models:
[a]Hospital mortality ~ (1|hospital of ICU admission) + PNR.
[b]Hospital mortality ~ (1|hospital of ICU admission) + PNR + comorbidities + age + admission type.
Cell indicating significant result.
PNR calculated including only registered ICU nurses and ICU patients.

in-hospital mortality of ICU patients. This association suggests that it is not the actual number of patients treated by a nurse, but the overall workload during the treatment of these patients that is essential for their outcome.

Previous studies on the association of nursing workload, expressed as PNR, with in-hospital mortality show contradictory results. A systematic review concluded that increased nurse staffing is associated with a lower in-hospital mortality (8), but this review included studies performed on different types of wards and not exclusively on ICUs, which could be an explanation for the different finding. Sakr et al (15) found that a PNR of greater than 1.5 was independently associated with a lower risk of in-hospital mortality in ICUs (OR, 0.69; 95% CI, 0.53–0.9; $p < 0.001$). In contrast, the literature review and meta-analysis of Numata et al (6) did not show an association between PNR and in-hospital mortality in ICUs, which confirms our findings. We believe that the PNR is not an appropriate measure for in-hospital mortality in ICUs and that it is better to use the NNR since NAS measures all the work that is being done in caring for each individual patient, both at the bedside and on the ward (e.g., administrative tasks and caring for relatives). To the best of our knowledge, this is the first study to assess the association of workload per nurse, instead of crude number of patients per nurse, with in-hospital mortality. Some studies did investigate the association between nursing workload and in-hospital mortality where nursing workload was measured as the occupancy rate per shift or with the Therapeutic Intervention Scoring System 76 (16–19). In both studies, a distinction was made between high and low nursing workload and both studies found that patients with a higher nursing workload had a higher risk of in-hospital mortality. Similar results were found by Padilha et al (18), who concluded that high NAS values were associated with increased in-hospital mortality. However, all these studies did not take the available nursing capacity into account.

Our primary analysis included ICU patients (recovery unit and coronary care unit patients were excluded) and registered ICU nurses (student- and non-registered ICU nurses were excluded) because the NAS was originally developed to be used for this type of patients and nurses. Other previous studies often did not explicitly describe their inclusion criteria, hampering comparison of the results. Although student nurses also partly take care of the present workload, and therefore can lower the average workload, guiding these student nurses can also be time consuming for the registered ICU and thus increase the workload. Because we were not sure how these effects might influence the results, we therefore performed a sensitivity analysis which showed similar results. This result might partly be explained by the relative low number of student nurses compared with the registered nurses in Dutch ICUs. In our data, we did not have information available on the years of nursing experience. Although our sensitivity analyses (Table S2, Supplemental Digital Content 2, http://links.lww.com/CCM/E935; and Table S3, Supplemental Digital Content 3, http://links.lww.com/CCM/E936) did not suggest that the outcome is associated with the type of nurse, further research should point out whether the years of experience of the ICU nurse are of influence on the outcome.

A limitation of our study is that our data contained information of only 15 out of 82 Dutch hospitals. However, these 15 ICUs form a representative sample of Dutch ICUs regarding size, type, and geographical location of the hospitals. Another limitation of the study is the retrospective design. Due to this retrospective design, we can only assess associations and no causalities. Furthermore, because we use routinely collected data for retrospective analyses, we were not able to correct the missing data, for example, the missing NAS scores, in a later phase of the study. Finally, a limitation of the study is the percentage of patients (15%) with missing NAS values which were excluded from the analysis. This potentially could lead to some biased results, however, as patients with and without NAS scores showed similar patient characteristics (Table 3) and in-hospital mortality rates we assume that the missing values appear randomly and will not influence our results.

Miranda et al (9) suggest that one FTE nurse corresponds approximately to the work of 100 NAS points. However, this score was not empirically justified and they did not explicitly recommend this ratio as optimum in the context of in-hospital mortality. Until now, it is unclear which NAS score per ICU nurse is optimal. Based on our results, we suggest that one registered ICU nurse should not provide more than 61 NAS points per day. However, more research with more ICUs, preferably in multiple countries, is needed to develop a strong evidence-based recommendation and a clear cutoff point. Furthermore, the NAS is developed specifically for critical care settings, which makes the NNR not a useful indicator for in-hospital mortality in noncritical care settings. Therefore, results of this study are not applicable to other clinical care settings. This study gives a good indication for the usefulness of the NNR compared with the PNR when relating nursing workload to in-hospital mortality. The results could be used for staffing nurses more adequately due to a broader knowledge on the impacts of nurse staffing on patient outcome. ICU managers could use these results to benchmark their current NNRs and to reconsider whether the nurses on their ICUs have a workload which is too high to provide care without a higher chance on in-hospital mortality for their patients. Consequently, ICU nurses could be deployed more efficiently while supporting higher quality of care in terms of survival among their patients. Further research should be performed on the generalizability of these results to ICUs in other countries.

CONCLUSIONS

The ratio of ICU patients per nurse is not associated with in-hospital mortality in ICUs while the nursing workload, expressed as the NNR, is positively associated with in-hospital mortality. Therefore, we conclude that it is more important to focus on the workload that the patients generate instead of the actual number of patients.

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