Predicting patient nurse-level intensity for a subsequent shift in the intensive care unit: A single-centre prospective observational study

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Abstract

Background

A dynamic optimized nurse staffing model for the Intensive Care Unit (ICU), requires a tool for monitoring nurse-level intensity with validated cut-offs to identify patients requiring 1:1, 2:1 or 3:1 patient-to-nurse ratios.

Objectives

We aimed to determine the Nursing Activities Score (NAS) cut-off values which can best distinguish between high, average and lower nurse-level intensity as unanimously perceived by care providers, and to evaluate whether these NAS cut-offs allow to predict nurse-level intensity in the next shift or the same shift the next day.

Design

A prospective observational study.

Setting

9 ICUs in a Belgian tertiary care center.

Participants

All 3295 patients admitted between March 20, 2013, and September 12, 2013 were included. NAS was quantified at the end of each shift using automatically derived and manually entered care information. Additionally, 412 nurses, 24 nurse managers and 37 physicians rated perceived nurse-level intensity.

Methods

We first assessed concordance between nurses', nurse managers' and physicians' perceptions of lower (3:1 patient-to-nurse ratio), average (2:1 patient-to-nurse ratio) and high (1:1 patient-to-nurse ratio) nurse-level intensity. Next, receiver operating characteristic (ROC) analysis was applied to determine the NAS cut-offs that best distinguish between different levels of perceived intensity for cases with concordant opinions. Last, logistic regression analysis was applied to estimate the ability of these NAS cut-offs to predict low and high perceived intensity during the next shift and during the same shift the next day.

Results

Nurses', nurse managers' and physicians' perceptions were concordant in 57.1% ($n = 4693$) of cases, mostly concerning lower or average intensity. Optimal NAS cut-offs for lower and high intensity patients equaled 52.7% and 69.8%, respectively. The lower intensity NAS cut-off showed 74.0% accuracy to predict lower intensity in the next shift and 75.9% accuracy to predict lower intensity for the same shift the next day. The high intensity NAS cut-off showed 67.9% accuracy to predict high intensity in the next shift and 72.0% accuracy to predict high intensity for the same shift the next day.

Conclusions

NAS cut-offs could contribute considerably in predicting patient nurse-level intensity, and thus patient-to-nurse staffing ratios, in the next shift or day. Identification or prediction of high intensity, nevertheless, appears most complex and requires further study. Future studies need to account for the many confounding variables which complicate nurse staffing planning.

Keywords

Intensive care units

Critical care

Nursing activities score

Workload

Statistics & numerical data

Surveys and questionnaires

Physicians

Nurses

Manpower

What is already known about the topic?

- The Nursing Activities Score allows for the demands of critically ill patients to be assessed on a shift-by-shift basis. The tool has been extensively validated and is used by intensive care unit managers across the globe to make evidence-based staffing decisions.
- The Nursing Activities Score has initially been designed starting from specific nursing activities and summation of time consumed. Less is known about the clinical judgement of patients' nurse-level intensity as a reference to validate the Nursing Activities Score, indicating the patient-to-nurse ratio to provide adequate and safe care.
- Like other nursing workload measurement tools, the Nursing Activities Score relies solely on nurses' reports and perceptions, whereas other health professionals may also contribute to an adequate estimation of the stability of a patient's nurse-level intensity over time.

What this paper adds

- In this prospective observational study, the subjective appreciation of nurse-level intensity by more than 400 nurses, nurse managers and

physicians of 8215 patient shifts correlated rather good concerning the large group of normal intensity patient-shifts, but unanimity on high intensity shifts requiring a patient-to-nurse ratio of 1:1 was rare.

- Receiver Operating Characteristics analysis suggested that optimal Nursing Activities Score cut-offs for lower and high intensity patients equaled 52.7% and 69.8%, respectively.
- These Nursing Activities Score cut-offs contributed considerably in predicting patient intensity both in the immediate following shift as well as in the same shift the next day.

1. Background

Providing adequate nurse staffing may be a cost-effective hospital management strategy to improve quality of care and safety. However, cutting expenses at the cost of reduced number of nurses staffed or a downgraded level of skill mix may be detrimental ([Rothberg et al., 2005](#); [Needleman et al., 2006](#); [Aiken et al., 2014](#)).

This may be particularly true for the Intensive Care Unit (ICU) where increased nurse staffing is associated with reduced mortality, morbidity, and shortened ICU-stay in several meta-analyses ([Kane et al., 2007](#); [Aragon Penoyer, 2010](#); [Numata et al., 2006](#); [West et al., 2009](#); [McGahan et al., 2012](#)). Previous studies confirmed the aforementioned association particularly in patients with a high risk of death and at a patient-to-nurse ratio exceeding 2.5 patients per nurse. ([West et al., 2014](#); [Neuraz et al., 2015](#)). Not only suboptimal nurse staffing, but also increased clinical workload – as reflected by patient turnover and the number of life-sustaining medical procedures – are inversely associated with survival ([Neuraz et al., 2015](#)).

Although inherent limitations of these studies, including their retrospective and observational design preclude conclusions about causality, health authorities worldwide did not wait for the ultimate confirmatory evidence to apply or propose mandatory nurse staffing ratios. In the US, several states require by law a maximum of one or two patients per nurse, depending on the type of unit (ICU or Emergency Room (ER)) ([Coffman et al., 2002](#)) or on the stability of the patient ([American Nurses Association 2015](#)). Similarly, the College of Intensive Care Medicine of Australia and New Zealand defines a minimum standard of 1 nurse per single critically ill patient, and 1 nurse per two lower acuity patients ([College of Intensive Care Medicine of Australia and New Zealand 2011](#)). According to Belgian law, two nurses, of which at least one with a special ICU-qualification,

must be present per six ICU-patients. Furthermore, “the nursing team must adapt to the activities” yet, no further specification is provided ([Federal Public Service Health Food Chain Safety and Environment 1998](#)).

As nurse-level intensity varies strongly among ICU patients ([Kiekkas et al., 2008](#)), harmonizing available nurse staffing with the actual clinical workload on a day-to-day basis probably leads to the safest patient care. Therefore, dynamic staff allocation strategies require a valid tool to accurately assess the needs of patient care at any time in the unit. One such tool is the Therapeutic Intervention Scoring System (TISS). This tool originally contained 57 items, but modified versions with 28 items (TISS-28) and 76 items (TISS-76) are used more frequently ([Cullen et al., 2020](#); [Keene and Cullen, 1983](#); [Miranda et al., 1996](#)). The latter revealed an inverse association between workload per nurse and risk-adjusted odds of survival ([Lee et al., 2017](#)). Although the TISS-28 explains 86% of the TISS-76 ([Miranda et al., 1996](#)), it only accounts for 43% of nurse workload ([Miranda et al., 1996](#)). In contrast, the Nursing Activities Score (NAS) covers 81% of the actual nurses’ activities. This internationally validated tool is based on the TISS-28, enriched with 5 new items and 14 sub-items ([Miranda et al., 2003](#)). It is expressed as a percentage between 0% and 177%, where the volume of nursing care that one nurse can provide during one shift equals 100% ([Miranda et al., 2003](#)). Several studies identified the NAS as the most appropriate tool to evaluate the intensity of care ([Padilha et al., 2010](#); [Padilha et al., 2015](#); [Gonçalves et al., 2007](#); [Ferreira et al., 2017](#); [Macedo et al., 2016](#)), and consequently risk of mortality and morbidity ([Padilha et al., 2008](#)). A Belgian single-center study revealed that NAS could identify differences in nursing care workload between consecutive shifts, and could therefore be a guide for shift-by-shift staff allocation ([Debergh et al., 2012](#)). Consensus-derived NAS cut-off values for differentiating between lower and high nurse-level intensity patients would facilitate the development of a dynamic optimized nurse staffing model. Such cut-offs should go beyond the initial validation based on summation time consumed per nursing act and rely on real-life clinical judgement identifying patients that can be adequately taken care of in the setting of 3:1, 2:1 or even 1:1 patient to nurse ratio. The importance of assessing nurses’ work in the ICU through a consensus-driven approach, meaning that both nurses’ as well as physicians’ views are included, was already recognized in the development of the NAS. Physicians and nurses jointly identified patient-

condition-related nurse activities that may influence the use of nursing time in the ICU ([Miranda et al., 2003](#)).

For the development of such a dynamic staffing model, an adequate estimation of the “stability” of the workload over time in a given patient is crucial. For example, would a patient requiring a 1:1 patient-to-nurse ratio in the morning still need this in the afternoon of the same day? In this perspective, two time windows are particularly of interest: 1) to know how many nurses are needed for the next shift based on the actual shift, which is crucial for nurse rostering, and 2) to predict nurse staffing needed for the same shift the next day, which allows more anticipated planning or modelling of nurse staffing.

Therefore, the aim of this study was to determine the NAS cut-off value which can best distinguish between lower, average and high nurse-level intensity ICU patients as unanimously perceived by care providers. Furthermore, we aimed to evaluate whether these NAS cut-offs allowed to predict care intensity in the next shift, or in the same shift during the next day.

2. Methods

2.1. Study design

This single-center prospective observational study involved a multicomponent quantitative data collection from six ICUs and three lower acuity units between March 20, 2013, and September 12, 2013. The study was conducted in University Hospitals Leuven, Belgium, a tertiary care center with 1995 beds. The six ICUs have a patient-to-nurse ratio of 2:1. The three lower acuity units have a higher patient-to-nurse ratio, ranging from 3:1 to 5:1.

All patients admitted to these units during the study period were included. All ICU nurses involved in direct patient care, ICU nurse managers and intensive care physicians participated to this study. Physicians or nurse managers who conducted exclusively non-clinical activities during the study time-window did not participate in this study. The aims and design of the study were explained to all participating health care professionals at multiple occasions.

2.2. Study measures

To quantify NAS-defined care intensity, the hospital's Patient Data Management System (PDMS) was used. TISS and NAS were introduced upon the implementation of the PDMS in 2006, but their clinical use had not been implemented. For this study, PDMS was reconfigured to provide: (1) items automatically derived by connected devices (e.g. electrocardiogram registrations); (2) therapeutic entries (e.g. arterial line or wound care registration); (3) medical prescriptions performed (e.g. total hydration); (4) monitoring and titration; (5) hygiene procedures; (6) mobilization and positioning of the patient; (7) support and care of relatives/patients; and (8) administrative and management tasks plus medical interventions. The latter 5 items were manually entered at the end of each shift into the PDMS for the purpose of this study. These items generated - on a daily basis and according to published guidelines - one overall day-NAS and one specific shift-NAS per patient ([Debergh et al., 2012](#)). Shifts were defined as morning (7am to 14.39pm), evening (14.40 pm to 22.19 pm) and night (22.20pm to 6.59am). The day-NAS was the sum of the maximum scores for each item scored during the specific day.

Patients were categorized into high, average and lower nurse-level intensity as perceived by nurses, nurse managers and physicians, who were all blinded for the actual NAS. During the second half of their shift, nurses completed a care intensity perception survey in which they were asked the following question: "What is your opinion on the workload for nurses caring for this patient?". Response categories were: (1) High nurse-level intensity, i.e. 'A critically ill patient requiring more attention than a typical ICU patient (requiring a patient-to-nurse ratio of 1:1)'; (2) Average nurse-level intensity, i.e. 'A typical ICU patient (requiring a patient-to-nurse ratio of 2:1)'; or (3) Lower nurse-level intensity, i.e. 'A lower intensity patient (requiring a patient-to-nurse ratio of 3:1)'. Nurse managers and physicians were only surveyed once a day during weekdays. Missing data were checked on a daily basis, and non-responders were asked to complete the information as soon as possible, at the latest the next day. For seven out of nine participating units, NAS items were collected for all shifts, in 2 units however, data collection during evening and night shifts was considered unfeasible. The NAS cut-offs were determined based on patient-shifts classified unanimously by nurses, nurse managers and physicians as high, average or lower intensity.

Given their role in providing essential items for the calculation of the NAS (see just above) several nurse characteristics (age, gender, years of experiences,

employment, and education (advanced bachelor in emergency and intensive care)) were collected. Also, some basic patient characteristics (age, gender, and length of stay) were registered.

2.3. Statistical analysis

Data were presented as percentages, means $\pm$ SD or medians (25th- 75th percentile), and eventually grouped in contingency tables, as appropriate. Data were compared using Student's *t*-test, Chi-square test, and Mann-Whitney U test. Receiver operating characteristic (ROC) analysis is applied to determine the NAS cut-offs that best distinguish between different levels of intensity. The area under a ROC curve (AUC) represents the overall discriminatory ability of the test, where a value of 1.0 denotes perfect ability, and a value of 0.5 denotes no ability. The potential for a given NAS cut-off-based intensity level to predict care intensity during the next shift and during a same shift during the next day, was estimated by logistic regression models. For this purpose, the data set was evenly split into a construction and a “naïve” validation set. In order to avoid over-sampling of long-stay patients, no more than 10 consecutive shifts were taken into account in one patient.

Statistical analysis was performed with JMP® SAS software. Copyright ©2016 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

2.4. Ethical approval

The study protocol was approved by the Medical Ethics Committee University Hospitals Leuven (ML 8559). Given the observational design of the study, the need for informed consent was waived.

3. Results

3.1. Sample description

During the study period, a total of 3295 patients were included, of which 1972 admitted to one of six ICUs, and 1323 to one of three lower acuity units. The population was predominantly male (62%), with a mean age of 59 (SD 22.2) years, and median length of stay of 2.8 days (Q1: 1.1, Q3: 5.9).

The majority of nurses ($n = 412$) was female (70.4%), with a mean age of 41 (SD 11.8) years, and 17.2 (SD 11.9) years of experience. Three out of four nurses (74.0%) had a specialized degree in intensive and emergence care. There were no relevant differences in demographic characteristics nor level of education of nurses across units.

Nurses provided items allowing the PDMS to calculate 42 568 shift-NAS, resulting in 16 780 day-NAS. The nurses moreover provided their perception of optimum patient-to-nurse ratio (nurse-level intensity) for 40 246 patient-shifts. Twenty-four nurse managers completed 9891 care intensity perception surveys, of which 9751 (95.5%) could be linked to the NAS-scores for the corresponding shift. Thirty-seven physicians completed 8807 care intensity perception surveys, of which 8713 (98.9%) could be linked to the corresponding NAS. Indeed, for less than 5% of surveys no corresponding NAS was available due to missing NAS-items when patients went to the operating theater for a long period of time, were admitted close to shift ends.

3.2. Nursing activities score

The average day NAS was 61.5% (SD 21.1%). Of the 42 568 shift NAS, 15 437 were morning shift scores, 13 665 evening shift scores, and 13 466 night shift scores. [Table 1](#) displays findings for NAS across shifts, and across ICUs and lower acuity care units. Differences across shifts and type of units were observed. To interpret the findings in terms of average workload per nurse, for example, the average day NAS of 65.1% on ICUs would translate to an average 130.2% NAS workload per nurse (as default staffing is 2 patients per nurse in these units). As previously mentioned, a NAS workload of 100% is supposed to consume 100% of a nurses' time.

Table 1. NAS day, morning, evening and night scores.

	Overall		Intensive care units		Lower acuity care units	
	n	mean (SD)	N	mean (SD)	n	mean (SD)
Day (overall)	16 780	61.5% (21.1%)	12 893	65.1% (19.8%)	3887	49.6% (21.0%)
Morning	15 437	55.0% (19.6%)	11 578	58.5% (18.4%)	3859	44.4% (19.1%)
Evening	13 665	55.4% (18.0%)	12 127	55.6% (17.8%)	1538	53.1% (19.4%)
Night	13 466	53.3% (16.4%)	12 001	53.6% (16.7%)	1465	51.1% (13.2%)

3.3. Differentiation in patient intensity by nurses, nurse managers and physicians

For 8215 patient-shifts the nurse-level intensity as perceived by both nurses', nurse managers', and physician' was available. Their opinions on patient intensity corresponded in 4693 (57.1%) cases, 24% of which were perceived as lower intensity patients, 32% as average intensity, and 1% as high intensity patients. [Table 2](#) illustrates degrees of agreement between healthcare professionals. Nurses and nurse managers identified more patients as high intensity compared to physicians, and agreement among all three groups on high intensity was poor.

Table 2. Degree of agreement in healthcare professionals' perception of care intensity.

	Agreement with nurses	Agreement with nurse managers	Agreement with physicians
Nurses' perception			
Lower nurse-level intensity (<i>n</i> = 14 300, 36%)	–	82.3%	78.9%
Average nurse-level intensity (<i>n</i> = 22 604, 56%)	–	70.6%	74.5%
High nurse-level intensity (<i>n</i> = 3342, 8%)	–	39.3%	17.9%
Nurse managers' perception			
Lower nurse-level intensity (<i>n</i> = 4179, 42%)	73.0%	–	75.2%
Average nurse-level intensity (<i>n</i> = 4823, 49%)	76.9%	–	76.8%
High nurse-level intensity (<i>n</i> = 889, 9%)	40.5%	–	18.7%
Physicians' perception			
Lower nurse-level intensity (<i>n</i> = 3719, 42%)	68.4%	73.3%	–
Average nurse-level intensity (<i>n</i> = 4797, 55%)	73.6%	70.1%	–
High nurse-level intensity (<i>n</i> = 291, 3%)	52.2%	51.4%	–

The average NAS was 44.2% (median: 40.7; Q1: 33.9 - Q3: 50.9) for patients perceived as lower intensity, 65.0% (median: 62.6; Q1: 57.3 - Q3: 72.7) for average intensity and 82.7% (median: 79.9; Q1: 72.3 - Q3: 90.9) for high intensity patients. Sup. [Fig. 1](#) displays the distribution of the data for lower intensity, average

intensity and high intensity patients. Mann-Whitney U test showed that differences across groups were all statistically significant ($p<0.0001$).

Fig. 1. Summary of data and findings.

3.4. NAS cut-offs that distinguished between lower intensity patients and other patients, and between high intensity patients and other patients

ROC analysis for the distinction between lower intensity patients (who can be adequately taken care of in a 3:1 patient to nurse staffing ratio) and other intensity patients (i.e. average and high intensity) provided an AUC of 0.89. The optimal NAS cut-off was smaller than 52.7%, with a sensitivity of 79.3% and specificity of 87.8% (Table 3). This cut-off value would classify 39.7% (14 160 of 35 706) of shift NAS measurements on ICUs as lower intensity, and 68.2% (4677 of 6862) of shift NAS measurements in lower intensity units.

Table 3. NAS cut-offs to distinguish between lower intensity patients and other patients, and between high intensity patients and other patients.

	High intensity versus average and low intensity	Lower intensity versus average and high intensity
Area under the curve	0.88	0.89

	High intensity versus average and low intensity	Lower intensity versus average and high intensity
Optimal threshold NAS	69.8%	52.7%
Specificity	78.4%	87.7%
Sensitivity	93.3%	79.3%
Accuracy	78.5%	84.1%
True negatives	3593	2382
True positives	90	1566
False negatives	18	410
False positives	990	333
Negative predictive value	99.5%	85.3%
Positive predictive value	8.3%	82.5%

ROC analysis for the distinction between high intensity patients and other (i.e. average and lower intensity) patients provided an AUC of 0.88. The optimal NAS cut-off was larger than 69.8%, with a sensitivity of 93.3% and specificity of 78.4% (Table 3). This cut-off value would identify 19.7% (7039 of 35 706) of shift NAS measurements on ICUs as high intensity, and 8.7% (597 of 6862) of shift NAS measurements in lower acuity units.

3.5. NAS cut-offs to predict care intensity in a next shift

2298 patients, for whom at least one pair of consecutive shift NAS points was available, were randomly split into a development sample (1149 patients and 7657 pairs of current shift and following shift NAS) and validation sample (1149 patients and 7232 pairs). Logistic regression analysis predicting whether the NAS in the consecutive shift would be below the cutoff for lower intensity (52.7%) showed 74.0% accuracy (negative predictive value: 77.8%, positive predictive value: 69.8%) (Table 4). Sup. Fig. 2 panels A and B present the ROC curves for the development and validation sample, respectively.

Table 4. NAS cut-offs to predict care intensity in the next shift and in the same shift the next day.

	Care intensity in the next shift		Care intensity in the same shift the next day	
	Below cut-off of 53.7 for lower intensity	Above cut-off of 69.8 for high intensity	Below cut-off of 53.7 for lower intensity	Above cut-off of 69.8 for high intensity
Area under the curve	0.78	0.73	0.80	0.77
Number of NAS pairs	7232	7232	5035	5035
Specificity	74.8%	67.9%	76.5%	72.2%
Sensitivity	73.0%	67.5%	75.0%	70.8%
Accuracy	74.0%	67.9%	75.9%	72.0%
True negatives	3014	4228	2236	3094
True positives	2341	680	1584	532
False negatives	864	327	528	219
False positives	1013	1997	687	1190
Negative predictive value	77.7%	92.8%	80.9%	93.4%
Positive predictive value	69.8%	25.4%	69.7%	30.9%

Logistic regression analysis predicting whether the NAS in the consecutive shift would be above the cutoff for high intensity (69.8%) showed 67.9% accuracy (negative predictive value: 92.8%, positive predictive value: 25.4%) (Table 4). Sup. Fig. 2 panels C and D present the ROC curves for the development and validation sample, respectively. An average intensity patient was most likely to remain so in the next shift. However, a lower intensity patient had a more than 50% likelihood to become an average intensity patient in the next shift in case that patient was not discharged. The development and validation samples generated very similar results.

3.6. NAS cut-offs to predict care intensity on the same shift during the next day

The random split development sample included 5444 pairs (current shift and same shift the next day) and the validation sample 5035 pairs. Logistic regression analysis predicting whether the NAS in the same shift on the next day would be below the cutoff for lower intensity (52.7%) showed 75.9% accuracy (negative predictive value: 80.9%, positive predictive value: 69.7%) (Table 4). Sup. Fig. 2 panels E and F present the ROC curves for the development and validation sample, respectively.

Logistic regression analysis predicting whether the NAS in the same shift on the next day would be above the cutoff for high intensity (69.8%) showed 72.0% accuracy (negative predictive value: 93.4%, positive predictive value: 30.9%) (Table 4). Sup. Fig. 2 panels G and H present the ROC curves for the development and validation sample, respectively.

Fig. 1 summarizes the main data and findings of the study.

4. Discussion

Our large PDMS-supported collection of Nursing Activities Score, combined with care providers' perception of nurse-level intensity in different intensive care and lower acuity units in a tertiary hospital, revealed a high nurse workload, exceeding a 100% NAS particularly for nurses working in 2:1 and 3:1 patient-to-nurse ratio's. Nurses, nurse managers and physicians agreed rather good on the large group of patient-shifts where a 2–1 patient-to-nurse staffing-ratio was deemed adequate. However, unanimity on “high intensity” shifts requiring a patient-to-nurse ratio of 1:1 was rare. Finally, NAS varied considerably between subsequent shifts in a single patient, and also for the same shift in the following days, which may complicate NAS-based planning of nurse allocation.

Daily NAS in our study were high, ranging from on average 49.6% in lower intensity units to 65.1% in the ICUs. By consequence, this will result in total NAS for one nurse regularly exceeding 100% both in 3:1 staffing and 2:1 patient-to-nurse staffing. Indeed, given the distribution of the NAS (Fig. 1) it is mathematically impossible to create pairs of average intensity patients or triplets of lower intensity patients not exceeding a NAS of 100%. According to the developers of the NAS, a NAS of 100% is supposed to consume 100% of a nurses' shift (Miranda et al., 2003). Given these findings, both the evolution of adverse events and nurse well-being should be closely and continuously monitored. This may be even more the case in the lower intensity units. Excessive workload may be partially prevented by conscientious and dynamic planning of nurse staffing, taking into account summation of NAS per pair or triplet of patients when allocating them to one nurse. This exercise is complicated, however, given the high variability in NAS for the same patient observed on a shift by shift basis.

Agreement between nurses, nurse managers and physicians on which patients require a lower or average staffing ratio was high. However, agreement on high

intensity patients requiring a 1:1 patient-to-nurse ratio was poor to very poor. Interestingly, nurse managers were more inclined to label patient shifts as high acuity as compared to physicians (9% vs 3%), yet they still failed to identify those patients who were experienced as high acuity by their bedside colleague nurses. Assuming that none of the clinician groups can be considered the gold standard we built our model based on only those patients where all three disciplines of health care professionals agreed. Therefore, the implementation of NAS cut-offs proposed in the actual paper or of any other tool will ultimately require clinical validation. Such validation goes beyond the caregivers' perception and should consider the impact of a given nurse staffing strategy on clinical outcome for the patients and well-being of the bed-side nurses. It may depend on the broader organization of care and on the case mix within the intensive care unit where such validation would be conducted.

Previous research has shown that the NAS can be used to assess workload per working shift ([Debergh et al., 2012](#)). This encouraged us to investigate the ability to take workload into account for manpower planning. Despite the within-patient variability in NAS between shifts, we found relatively good positive and negative predictive values both in models predicting the immediate following shift, as well as the same shift on the next day based on the proposed NAS cut-off for lower acuity patients. This relatively good predictive value, combined with the high rates of agreement (70% to 80% overlap) between nurses, nurse managers and physicians in labelling patient-shifts as lower acuity was reassuring. It could allow nurse managers and/or nurse staffing tools to identify a large group of patients (36–42% of all patients admitted to ICUs and lower acuity units) that could be safely taken care of in a lower staffing ratio in the next shift or day. However, this is not the case for the relatively small proportion of high intensity patients (3–9% of all patients studied). The agreement between different health care professionals was low, and the models were not performing too well either. This is not surprising in the context of an ICU. The unpredictable clinical evolution in the most severely ill patients is a typical feature of critical illness. Therefore, NAS-based nurse staffing tools should function at least at a (sub) unit level (rather than individual patient level) allowing to safely “absorb” potential mistakes in estimated staffing needs. Likewise, the identification of approximately 30% of patient shifts in the ICU as “lower intensity”, based on our cut-off, was an important and reassuring finding. It

may constitute some safety buffer for unforeseen high intensity shifts in the near future ([Dahl et al., al.](#)).

4.1. The present study has some limitations

First, our study was performed in only one Belgium tertiary referral university hospital. Although it validates the concept of a NAS cut-off in predicting nursing workload, these cut-off values themselves cannot be generalized to other ICUs as pathology and therapeutic environment may be very specific and determining for nurse staffing needs. Second, for practical feasibility, only NAS during weekdays were taken into account, as nurse manager and physician scores were not obtained in the weekend and on holidays. This may have influenced our findings, as weekend NAS have been found to be lower ([Debergh et al., 2012](#)). Also, for two units, NAS was only measured during the morning shifts. Third, the NAS itself has some limitations. Nursing is not a sum of clearly delineated activities. The simultaneous performance of activities makes it difficult to make a correct assessment of time required to complete these activities ([Gonçalves et al., 2007](#)). A face and content re-evaluation was performed in Italy, suggesting that the NAS needs a revision to be in accordance with current practice in ICUs ([Palese et al., 2016](#)). Indeed, a number of time-consuming activities are not or insufficiently taken into account in the NAS (e.g. turnover, documentation of care work interruption by telephone calls) ([Myny et al., 2012](#)). Also, the NAS questions about care intensity may be prone to subjective interpretation ([Vincent and Moreno, 2010](#)). Finally, quality of patient care and the well-being of the health care professionals in an ICU setting is probably determined by more than nurse to patient staffing ratios. For example, the presence of advanced practice nurses has been associated with a reduction in 30-day mortality. The contribution of other health care professionals, not in the least intensive care physicians, is also well documented. For example, a large UK retrospective cohort study found that hospital mortality is lowest at a patient-to-intensive care physician ratio of 7.5 ([Gershengorn et al., 2017](#)). Likewise, Neuraz et al. found that an insufficient patient-to-physician ratio above an observed maximum threshold of 14 was associated with an increased risk of mortality ([Neuraz et al., 2015](#)). The College of Intensive Care Medicine of Australia recommends an intensive care physician-to-patient ratio of 1 per 8–15 patients ([College of Intensive Care Medicine of Australia and New Zealand 2011](#)). Also allied health professionals contribute to safe patient care in the ICU ([Knight,](#)

2016). A large percentage of nurses and physicians perceiving care as inappropriate, identified good teamwork, mandatory family meetings, and formal communication training as potential solutions (Piers et al., 2014; Anstey et al., 2015; Piers et al., 2011).

5. Conclusions

This large observational prospective study on workload, as perceived by healthcare professionals and NAS at a patient-shift level, revealed that NAS cut-offs could contribute considerably in predicting patient-to-nurse staffing ratios in the next shift or day. However, quality of care and the safety of patients and nurses is determined by far more than nurse staffing and workload alone. Severity of illness can change very quickly, and identification or prediction of high nurse-level intensity patient-shifts appears most complicated. Therefore, nurse managers or nurse staffing tools should integrate additional parameters and incorporate buffers in order to safely absorb unavoidable mistakes.

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Karen Decock: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing - original draft. **Michael P. Casaer:** Conceptualization, Methodology, Investigation, Writing - original draft, Project administration, Supervision. **Fabian Guïza:** Methodology, Formal analysis, Data curation, Visualization, Writing - original draft. **Pieter Wouters:** Software, Data curation, Investigation, Writing - review & editing. **Mieke Florquin:** Investigation, Writing - review & editing. **Alexander Wilmer:** Investigation, Writing - review & editing. **Stefan Janssens:** Investigation, Writing - review & editing. **Sandra Verelst:** Investigation, Writing - review & editing. **Greet Van den Berghe:** Conceptualization, Investigation, Writing - original draft, Project administration, Supervision. **Luk Bruyneel:** Methodology, Visualization, Writing - original draft, Supervision.

Declaration of Competing Interest

None

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