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Association between patient classification systems and nurse staffing costs in intensive care units: An exploratory study

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ABSTRACT

Objectives: Nurse staffing costs represent approximately 60% of total intensive care unit costs. In order to analyse resource allocation in intensive care, we examined the association between nurse staffing costs and two patient classification systems: the nursing activities score (NAS) and nine equivalents of nursing manpower use score (NEMS).
Research methodology/design: A retrospective descriptive correlational analysis of nurse staffing costs and data of 6390 patients extracted from a data warehouse.
Setting: Three intensive care units in a university hospital and one in a regional hospital in Norway.
Main outcome measures: Nurse staffing costs, NAS and NEMS.
Results: For merged data from all units, the NAS was more strongly correlated with monthly nurse staffing costs than was the NEMS. On separate analyses of each ICU, correlations were present for the NAS on basic costs and external overtime costs but were not significant. The annual mean nurse staffing cost for 1% of NAS was 20.9–23.1 euros in the units, which was comparable to 53.3–81.5 euros for 1 NEMS point.
Conclusion: A significant association was found between monthly costs, NAS, and NEMS. Cost of care should be based on individual patients' nursing care needs. The NAS makes nurses' workload visible and may be a helpful classification system in future planning and budgeting of intensive care resources.

Implications for Clinical Practice

- The allocation of resources should be derived according to the needs of individual patients as assessed by the Nusring Activities Score.
- The Nusring Activities Score classification system would be beneficial for managers to match patient needs with nurse staffing requirements and costs.
- The Nusring Activities Score could be used in payment systems of reimbursement.

Introduction

The resourcing of nursing staff is a legitimate concern globally, especially in the benchmarking of intensive care units (ICUs). Benchmarking includes identifying the best practice measurement associated with a given quality or outcome (Finkler and McHugh, 2008). An analysis of human resource operating costs is needed within an ICU to determine if resources are properly allocated according to individual needs (Endacott, 2012; Wunsch et al., 2012). Labour costs are the most important cost driver and in a group of four European countries, the United Kingdom showed the highest labour costs relative to total ICU costs (Tan et al., 2012); this was due to the higher unit costs of ICU specialists and ICU nurses. Cost is connected to numbers of staff and simplified staffing parameters, such as nurse-to-patient ratio, were widely used in earlier times. However, a more precise method than nurse-to-patient ratio is needed to assess and monitor patients' needs and to classify nursing activities and specific interventions (Endacott, 2012; Wunsch et al., 2012; West et al., 2014).

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Classification systems measure patient illness severity and classify nursing activities into direct and indirect care. These have been used to quantify clinical performance and to explore the effects of workload on nurse sensitive patient outcomes (Miranda and Jegers, 2012; Kakushi and Martinez Evora, 2014; Lindqvist et al., 2014). Direct patient care comprises of nursing activities, such as hygiene and mobilisation, while indirect patient care involves administrative tasks and coordination. Studies of costs in hospital wards have explored differences in nursing resources using patient classification systems and different costs between diagnosis-related groups (Fagerström and Rauhala, 2007; Andersen et al., 2016). However, this approach has not been common in the benchmarking of ICUs and previous studies of ICU costs had methodological deficiencies (Moerer et al., 2007; Gershengorn et al., 2015; Araújo et al., 2016).

Research has involved workload studies, such as short time-period workload studies, for example, one-day prevalence studies and the use of scripts from existing databases without patient classification systems (Tan et al., 2012; Sakr et al., 2015). The Simplified Therapeutic Intervention Scoring System (TISS-28) was used to evaluate costs in Germany (Moerer et al., 2007) and Finland (Parviainen et al., 2004), whilst the Nine Equivalents of Nursing Manpower Use Score (NEMS) was used to measure nursing costs in Switzerland (Vincent and Moreno, 2010).

It has been hypothesised that the Nursing Activities Score (NAS) can be used as a bottom-up methodological approach to measure costs (Miranda and Jegers, 2012; Araújo et al., 2016) because its content is possibly more specific in assessing nurse activities when compared to the TISS-28 and NEMS. A bottom-up approach starts by assessing cost data for individual patients and measures time spent on nursing interventions, procedures and other tasks (Arthur and James, 1994); conversely, a top-down approach is used only when cost data can be assessed at the unit-level and staffing norms exist, such as the presence of one nurse for each patient on ventilator support (Halpern, 2009; Stafseth et al., 2011; Tan et al., 2012). With electronic systems and classification systems, bottom-up approach means that detailed data are collected at the bedside. To date, only one study from Brazil has used the NAS for cost analysis in ICU using both bottom-up and top-down approaches (Araújo et al., 2016). After implementation in our country, NAS and its relationship with nursing costs has not been examined.

The aim of this study was to analyse whether an association exists between the NAS, NEMS, and ICU nurse staffing costs. The costs of overtime and nurse staffing have been increasing for years (Miranda and Jegers, 2012), whereas the number of patients has remained rather constant (Flaatten and Kvale, 2003; Parviainen et al., 2004; Sakr et al., 2015). We investigated whether patient classification systems might be able to explain or identify ICU costs. Therefore, we hypothesised there is no correlation between NAS and NEMS and ICU nurse staffing costs.

Methods

Design and setting

A retrospective one year follow-up study using a descriptive correlational design of nursing costs was performed in four ICUs in Norway. Two public hospitals were voluntarily recruited, Oslo university hospital and Telemark hospital Skien, a regional non-university hospital. Three units from the university hospital were included, ICU-1, ICU-2, and ICU-3, while the fourth unit, ICU-4, was from the regional hospital (Table 1). The ICU-1 was the largest unit in terms of nursing staff and had the most complex patient case-mix of trauma, sepsis, and neurosurgical patients. The ICU-2 was specialised in neurosurgical patients, had fewer beds and patients than ICU-1. The ICU-3 had the highest number of ICU beds for post-operative surgical patients and trauma patients. The regional hospital (ICU-4) had a broad case-mix, as it was the only ICU in the hospital. All patients admitted during 2012 were retrospectively included in the study and data from ICU patient registers, which recorded all patient admissions, were made available. With regard to ICU-4, patients in day care and children were excluded and so were their nursing costs. This study focused on nurse staffing costs, therefore we excluded costs not directly related to actual patient care, such as those associated with maintenance staff, physicians, nurse managers and educators, accommodation and catering, heating, lighting, overheads, building amortisation and medication costs.

Table 1
Organisational structure of four ICUs in Norway, 2012.

	ICU-1	ICU-2	ICU-3	ICU-4	Total
Organisational Department	University, Division of Emergencies and Critical care	University, Division of Emergencies and Critical care	University, Division of Emergencies and Critical care	Regional, Division of Surgery and Emergencies	University: 3 Regional: 1
Patient case-mix	Trauma, sepsis, and post-operative surgical patients	Neurosurgical patients	Post-operative surgical patients and trauma	All surgical, medical, and paediatric patients	
Technical equipment	Artificial ventilation, RRT	Artificial ventilation	Artificial ventilation	Artificial ventilation, RRT	
Number of RN (FTE)	1	1	14	5	21
Number of CCN (FTE)	82	50	51	64	247
Number of non-nursing staff (FTE)	4	2.7	2	6	14.7
Total*** FTE per 1000 ICU days	29.8	35.5	23.0	26.9	Mean 28.8
Skill-mix: CCN of total number of nurses (%)	98.5	98	78.5	92	Median 91.75
Number of beds	11	7	14	5* + 9 beds for post-surgical care and subunit 6 beds for recovery	37* + 15 beds for post-surgical care
Number of patients on the unit/day Mean (SD)	8.8 (2.3)	5.3 (1.1)	5.4 (1)	4 (3.9)	23.5
Bed occupancy rate (%)	82.7	77.3	61.1	154**	Mean 93.8

RN = registered nurse, CCN = critical care nurses with 1.5–2 years of postgraduate education in critical care nursing, FTE = full-time equivalent, Patient case-mix = range of different categories of patients, RRT = renal replacement therapy.
* ICU beds, ** Bed occupancy rate for 5 ICU beds *** Overtime included.

Data collection

Data were extracted from four pre-existing quality systems with the same database software (IMEX, PasDoc, SPISS, and GAT Soft) and the Norwegian Intensive Care Registry. The following data were collected in an automatic script: information on the organisational structure of the ICUs (department, patient case-mix, level of nurse competence, skill-mix, number of full-time equivalents (FTEs), and number of beds and patients per day with bed occupancy), patient characteristics (age, gender, type of admission, length of stay (LOS), Simplified Acute Physiology Score (SAPS II)), patient classification scores (NEMS and NAS) and nurse staffing costs. One FTE is equivalent to the number of hours worked in one week by a full-time employee (Miranda et al., 2003), which is 35.5 hours per week in Norway. Nurse staffing costs were described as monthly basic costs (wages, social premiums, compensation for irregular working hours), external pool costs (nurses employed by agencies), internal pool costs (nurses employed by the hospital) and overtime costs. Data was imported into the data warehouse platform.

All costs were converted from Norweigan Kroner to Euro at 7.35:1 (The Norwegian Bank rate for December 2012). In 2012, the time of the study, annual wages for nurses in Norway were in the range of €58,463–65,361, depending on educational level and experience.

Classification systems NEMS and NAS

The NEMS was derived from the TISS-28 as part of the Biomed 1 Program of the Commission of the European Communities for Research on Intensive Care in Europe (EURICUS-1 project) (Miranda et al., 1996; Miranda et al., 1997). The NEMS is an index that measures workload performance by describing medical therapeutic interventions in terms of nine items: monitoring, intravenous medication, mechanical or supplemental ventilation, single or multiple vasoactive medications, dialysis techniques and special interventions within or outside the ICU. The index is weighted from 1 to 56 points, with higher numbers indicating higher workload and is assessed retrospectively once daily.

The NAS measures nursing workload at the patient level taking into account the average time consumption for therapeutic procedures and nursing activities. Nursing activities include hygiene, mobilisation, administrative activities, and psychological support for the patient and their family, in addition to patient care (Miranda et al., 2003; Padilha et al., 2010; Stafseth et al., 2011). The NAS consists of 23 items with sub-items, and the summed scores range from 1 to 177%. It can be calculated retrospectively on a per-shift or per-day basis. Individual item weights range from 1.2 to 32%, with each item representing the percentage of a nurse's available time that is spent on a specific activity (Miranda et al., 2003).

Statistical analysis

Data were extracted from the data warehouse and copied into the Statistical Package for the Social Sciences (SPSS) for Windows, Version 21.0 (IBM Corp., Armonk, NY, USA) for descriptive and statistical analysis. A data warehouse is a data storage facility (on an SAS platform) for storing electronic patient data and once extracted data can be analysed. Reporting data and data analysis from one or more system i.e. makes different data sources compatible for analyses. All statistical analyses were exploratory and descriptive. Patient age, gender, scheduled/unscheduled admission, length of stay (LOS), SAPS II, NEMS and NAS were presented as frequencies, percentages, and mean and standard deviation (SD) for normally distributed data or median and interquartile ranges (IQRs) for skewed data (Veierød et al., 2012). Data were collected from a high-quality national data set, and we did not control for missing data but we know that missing data is few and not likely to affect our statistical analyses. Where appropriate we used monthly data from each unit (10–12 observations).

Overtime as well as external and internal pool time was presented as percentages of total time and costs. Overtime was converted to FTE and analysed together with the number of nurses employed. The variables of interest were the average cost (in euros) per 1% of NAS and per 1 point of NEMS. These variables were determined by dividing the total nurse staffing costs for each ICU by the patients' NAS and NEMS for the whole year. Correlation analysis was performed to assess the relationship between monthly NAS and the following variables: monthly NEMS, basic costs, external and internal pool time, overtime and total nurse staffing costs.

Pearson's correlation coefficient was calculated with significance set to 0.05 and bootstrapped based on 2000 samples with bias, standard error (SE), and 95% confidence intervals (CIs). Bootstrap is a technique from which the sampling distribution of a statistic is estimated by taking repeated samples from the data set (Veierød et al., 2012) The strength of the correlation was defined as follows: r = 0.10–0.29, weak; 0.30–0.49, medium; and 0.50–1.0, strong (Cohen, 1988).

Ethical approval

Ethical approval was obtained from the Regional Committee for Medical and Health Research Ethics in Norway (REK 2011/2325) and from the Data Protection Officer in each hospital (PV 2011/15,341). The data did not involve sensitive information or information affecting patient care directly. Of the data extracted from the Norwegian Intensive Care Registry, data from one patient was excluded upon personal request to withdrawal from the registry.

Results

ICU and patient characteristics

Data pertaining to ICU characteristics and staffing costs were analysed. There were some differences in the characteristics of the four ICUs, as shown in Table 1. In Norway, a critical care nurse (CCN) has 1.5–2 years post-graduate education in critical care nursing whilst a registered nurse (RN) has a bachelor's degree. The highest proportion of CCNs was found in ICU-1 (98.5%) and ICU-2 (98%); ICU-4 had 92% whereas ICU-3 had the lowest proportion at 78.5%. Results of bed occupancy rate was 154% (ICU-4), based on five ICU beds, exceeded daily because of care to more than five patients. The mean number of nurses employed per ICU was 28.8 (SD = 5.3) FTEs per 1000 ICU days.

Characteristics of the patient sample (N = 6390) are summarised in Table 2. The mean age for all patients was 49.8 years (SD = 8.4), and 57% (3630) were male. Median LOS was short for ICU-3 (0.3 days, IQR = 0.2–0.8) and ICU-4 (0.6 days, IQR = 0.2–1.4) . The longer median LOS in ICU-1 (1.4 days, IQR = 0.4–5.1) and ICU-2 (2.0 days, IQR = 0.6–8.6) may be explained by the higher rates of more complex patients and unscheduled admissions (ICU-1 = 92.8%, ICU-2 = 76.7%). The ICU-4 had the highest median SAPS II and the oldest group of patients (mean age = 58.9 years, SD = 19.9). Median NAS (%) was lower for ICU-3 and ICU-4 than for the other ICUs, reflecting fewer complex patients and shorter LOS in ICU-3 and ICU-4.

Nurse staffing costs

As shown in Table 3, total nurse staffing costs were highest in ICU-1 because it employed 83 FTE nurses with overtime

Table 2
Patient characteristics, NEMS, and NAS in four ICUs (N = 6390).

	ICU-1	ICU-2	ICU-3	ICU-4	Mean
Number of patients	747	266	4076	1281	
Sex (% male/female)	63/37	60/40	56/44	56/44	57/43
Age in years Mean (SD)	50.3 (26.2)	38.5 (12.0)	51.6 (24)	58.9 (19.9)	49.8 (8.4)
Length of stay in days (LOS) Median (IQR)	1.4 (0.4–5.1)	2.0 (0.6–8.6)	0.3 (0.2–0.8)	0.6 (0.2–1.4)	
Patients with LOS < 8 h (%)	23.8	21.3	54.7	34.3	
Total ICU-days for the unit	3225	1611	1973	2822	
Total post-surgery days for the unit	104	40	1160	*	
Type of admission: Scheduled (%)	7.2	23.3	35.1	2.3**	
Type of admission: Unscheduled (%)	92.8	76.7	64.9	45	
SAPS II Median (IQR)	26.0 (15.0–43.0)	34.0 (22.5–46.5)	24.0 (15.0–33.0)	38.0 (27.0–48.0)	30.5
NEMS Mean points per patient/day (SD)	30.5 (10.7)	27.1 (10.1)	15 (10.9)	27.6 (8.6)	25.0
NEMS Total points for 1 year	132,550	58,969	81,116	95,938	
NAS Median% per patient/day (IQR)	147.2 (137.9–153.0)	128.6 (106.7–142.1)	82.2 (62.9–106.9)	93.6 (67.5–108.3)	
NAS Total% for 1 year	489,460	211,146	286,143	244,046	

SAPS II = Simplified Acute Physiology Score (only one measurement for the first 24 h in ICU), NEMS = Nine Equivalents of Nursing Manpower Use Score, NAS = Nursing Activities Score, IQR = interquartile range.
* Included in the total ICU-days for the unit, ** Not specified 52.7%.

comprising of 18.2% of total hours worked. Total nurse staffing costs per 1% of NAS ranged from €20.90 to €23.10; thus, the variation was small between the ICUs and this was found despite the variability in the patient case-mix, ICU size and specialisation. Conversely, the lowest nurse staffing costs per NEMS point was €53 for ICU-4, while the costs for the other three units were approximately €80 per point. The results of costs in ICU-4 could be affected by the fact that 45% of the patient admissions were unscheduled and that 52.7% of the admissions were not specified if they were scheduled or unscheduled. Additionally one third of the patients in ICU-4 had a LOS < 8 hours related to the patients not being the usual type of patients admitted to most ICUs. The patient case-mix in ICU-4 with medical patients (unscheduled or not specified) resulted in higher mean NEMS score compared to ICU-3 with post-operative surgical patients. Using NAS, we estimated nurse staffing costs per patient/day for a university hospital ICU as €3135 (ICU-1) and for a regional ICU as €1956 (ICU-4).

For merged monthly data from all ICUs, the correlation between NAS and all cost variables, with the exception of external pool costs, was significant, as shown in Table 4. A strong correlation was found between NAS and basic costs (r = 0.869), as well as between NAS and total nurse staffing costs (r = 0.861). The correlations found for NEMS were weaker than those found for NAS but still strong with basic costs (r = 0.714) and with total nurse staffing costs (r = 0.685) (Table 4). The nurse staffing costs per NEMS point showed divergent results in € compared to NAS% (Table 3). The correlation between monthly NAS and total nurse staffing costs for all units is shown in Fig. 1. The test for bootstrap samples confirmed the observed correlation results for NAS, NEMS, and total nurse staffing costs, with bias of 0.00; SE for NAS and total nurse staffing costs was 0.03 (95% CI = 0.79–0.92), while for NEMS and total nurse staffing costs it was 0.08 (95% CI = 0.49–0.81).

Specific analyses of NAS and basic costs per month for each ICU showed no significant correlations (r = -0.230–0.477); similarly no significant correlations were found between NAS and external overtime costs per month for each ICU (r = 0.129–0.700), (Fig. 2). Based on our findings, we deduce the low number of observations (10–12 months per ICU) cannot detect significant correlation per unit.

Discussion

In this one year follow-up study, a strong correlation exists between assessed NAS and NEMS, and monthly nurse staffing costs in merged data from all ICUs. The NAS appears to work better than the NEMS for explaining nurse staffing costs. Our findings showed that total nurse staffing costs increased with higher NAS per month (ICU-1), thereby potentially introducing bias in merged data. If nurse leaders in resource allocation used the NAS for staffing adjustment (to staff up or down), this would be visible in the monthly costs.

Resource allocation and use of patient classification systems

The NAS allows a unique in-depth analysis of resource use assessing care needs. Classification systems using a bottom-up

Table 3
Nurse staffing costs, overtime, and absence time over 12 months for four ICUs, 2012.

	ICU-1	ICU-2*	ICU-3	ICU-4	Total (n = 4) Mean
Total nurse staffing costs (€1000)	10,419	4643	6611	5110	6695.7
Total nurse staffing costs per 1% NAS	21.3	22.0	23.1	20.9	21.8
Total nurse staffing costs per 1 NEMS point	78.6	78.7	81.5	53.3	73.0 Median 78.7
Overtime costs over total nurse staffing costs (%)	5.9	6.6	5.1	5.9	5.9
External pool costs over total nurse staffing costs (%)	2.4	6.9	3.8	4.6	4.4
Internal pool costs over total nurse staffing costs (%)	4.4	3.9	3.1	1.6	3.3
Overtime over total working time (%)	18.2	14.9	10.9	10.0	135
Absence time (e.g. sick leave, vacation, education) over total working time (%)	27.9	29.4	19.5	NA	25.6 Median 27.9

Overtime = working time in excess of that planned, External pool = nurses employed by agencies, Internal pool = nurses employed by the hospital, NA = data not available.
* Data cover only 10 months because ICU closed in summer.

Table 4
Correlations between monthly nurse staffing costs, NAS, and NEMS for all four ICUs in 2012 (N = 46).

	NAS r	p-value	NEMS r	p-value
1. Basic costs	0.869*	<.001	0.714*	<.001
2. External pool costs	−0.181	.229	−0.312*	.035
3. Internal pool costs	0.707*	<.001	0.503*	<.001
4. Overtime costs in the unit	0.466*	.001	0.357*	.015
5. Extra costs (2 + 3 + 4)	0.513*	<.001	0.271	.068
6. Total nurse staffing costs (1 + 5)	0.861*	<.001	0.685*	<.001
NAS	1		0.888*	<.001
NEMS	0.888*	<.001	1	

NAS = Nursing Activities Score, NEMS = Nine Equivalents of Nursing Manpower Use Score, r = Pearson's correlation coefficient, p = probability of error.
* Correlation is significant at the 0.05 level (2-tailed).

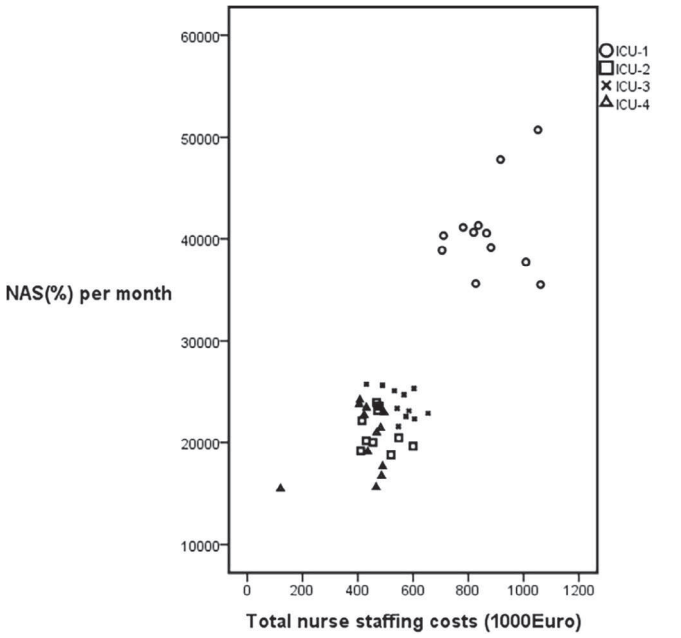

Fig. 1. Correlation between monthly Nursing Activities Score (NAS) and total nurse staffing costs (€1000). Results of Pearson's correlation between mean monthly NAS and total nurse staffing costs per month, where each point represents one month in 2012 for a specific ICU.

approach make nurse workload visible and provide an objective base for staffing and resource allocation (Miranda and Jegers, 2012). Our study found nurse staffing costs per 1% NAS to be quite similar in all four ICUs. The NAS offers an indicator of staffing needs and is more relevant to nursing workload than staffing based simply on the number of admitted patients or LOS (Endacott, 2012; Miranda and Jegers, 2012; Araújo et al., 2016). Our main findings, using nurse staffing costs in 2012 show that it is possible to describe costs in relation to patients' care needs and interventions. For example in ICU-4 the median NAS was 93.6 which equates to €1956. If the unit have 100 patients days it represents €195,600 and in ICU-1 (with same calculation) it will result in €313,500; this will of course have implications for the units. Based on our findings, we deduce that it was not the daily practice of nurse leaders in the examined ICUs to use the collected NAS information for staffing needs and costs.

To our knowledge the use of NEMS in the reimbursement of hospitals for staffing costs occurs in only two countries, Switzerland and Germany (Perren et al., 2012). The NAS could be a prospective payment system.

Work policies and practices including nursing activities and staff patterns in terms of numbers of additional staff differ among countries (Lindqvist et al., 2014; West et al., 2014). In our study, the basic staffing costs were related to nurses being specifically trained in ICU nursing at a postgraduate level and the salaries associated with this. The NAS does not consider what kind of skill-mix the nurses have. However, earlier studies have showed that both the number of staff and their level of education are relevant for quality of care (Aiken et al., 2014; West et al., 2014).

Methodology to explore nurse staffing costs in benchmarking

Our methodology to explore nurse staffing costs provides a user-friendly, integrated system, which is valuable for managers and in benchmarking. The allocation of resources should derive from patients' care needs and our results suggest the NAS is a reliable tool to measure nurse staffing costs. We found that the nurse staffing costs per 1% NAS, from €20.9 to €23.1, were independent of the patient case-mix or size of ICU. The NAS results exhibited only small differences between all units, suggesting that NAS is a better tool than NEMS to map nurse activities and staffing. This might be explained by differences in patient case-mix in ICU-4. Previous studies in different countries found that ICU costs could be largely explained by differences in patient case-mix (Tan et al., 2012; Wunsch et al., 2012; Gershengorn et al., 2015). It is also common to associate costs with the density of available acute care beds per inpatient, however, we did not examine this variable in our study.

We estimated nurse staffing costs per patient/day from the median NAS and found them to be between €1899 and €3135 in 2012. This was comparable to the value of €1379 in 1997–1999 (Flaatten and Kvale, 2003) but differs considerably from figures in 2008 (Tan et al., 2012), when daily nurse staffing costs were found to be €438 in France and €752 in the UK. In exploring nurse staffing costs, we converted costs to FTE, and found a mean of 28.8 nurses per 1000 ICU days in 2012. On the other hand, a European study using data from 1999 to 2000 reported that ICUs in the UK had a mean of 22.6 FTE nurses, while those in France had a mean of 11.5 (Negrini et al., 2006). There is a tremendous variability across countries with regard to ICU staffing by nurses, critical care nurses or non-nursing staff. Nurse staffing costs will be high if all nurses should be CCNs and questioned if resources are properly allocated to patients' needs and interventions. Our data are five years old and costs have increased. This will, however, not affect the major findings and the conclusions in the study. Studies evaluating costs among ICUs use different methodology, making comparisons challenging. For the future, a tool such as NAS, has the potential to determine nursing skill mix, nursing budgets and reimbursements.

Limitations and strengths

A potential limitation of this study involves the quality of data from pre-existing data systems and, specifically, the unknown extent of inaccuracy. However, both NEMS and NAS were recorded

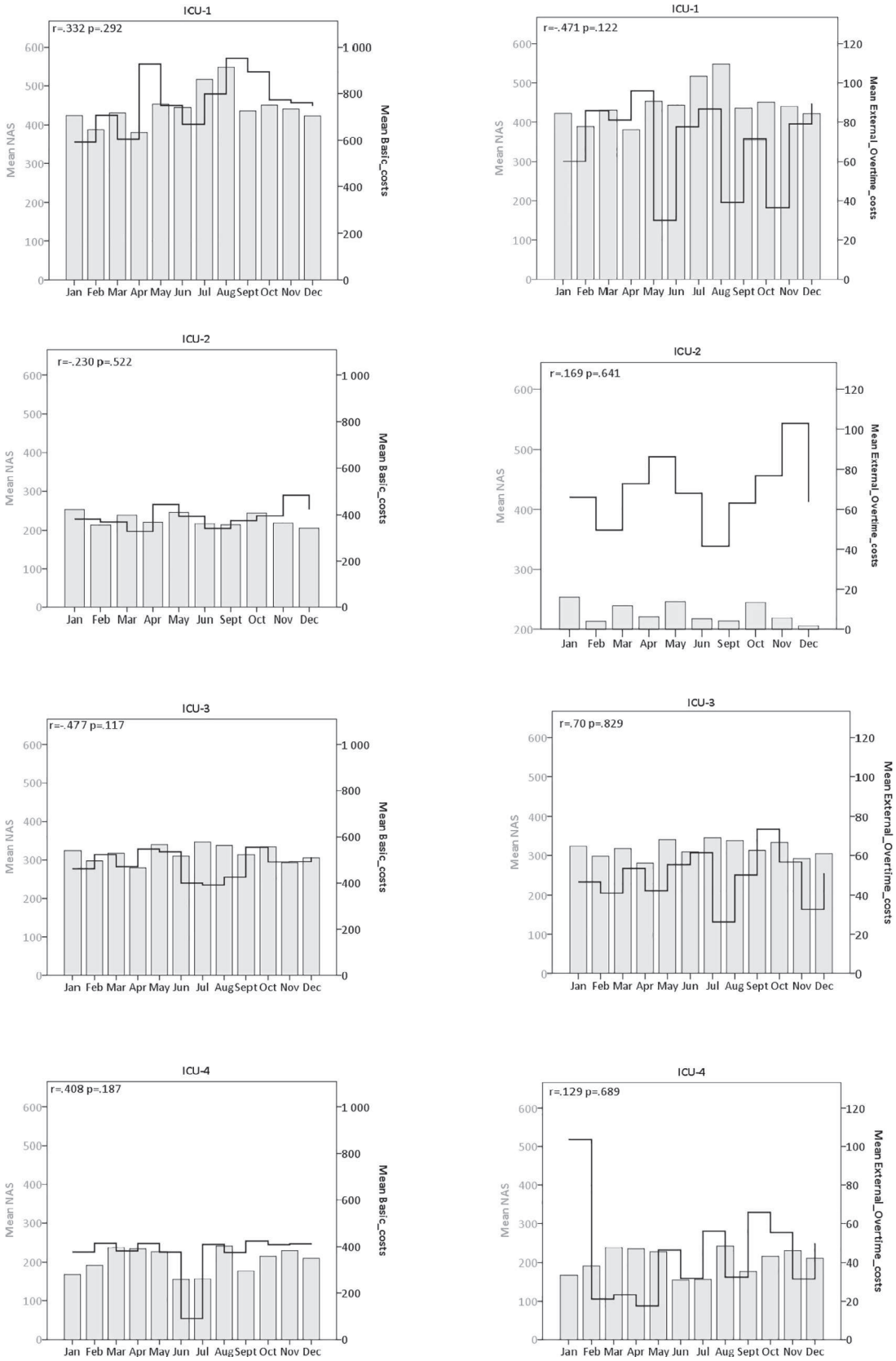

Fig. 2. Correlation of monthly NAS with nursing staff basic costs and external overtime costs in each ICU. Left hand-side charts: the line represents monthly basic costs (€1000) and the bars represent monthly NAS (%). Right hand-side charts: the line represents monthly external overtime costs (€1000) = external pool costs and the bars represent monthly NAS (%). Pearson's correlation (r) and p-value (p) are shown on each chart.

retrospectively and checked daily for coherence, owing to the potential for bias. Another potential issue is missing data as a result of non-documentation by staff. The systems from which we collected the data were frequently used both internally and nationwide and compile a high-quality national dataset. We did not test the data for reliability because of the excessive cost of retrospective data checking. This study involves a small-scale test of data from two hospitals in one country. For the results to be generalised to other hospitals, further research is needed.

A strength of this study was the inclusion of both university and regional hospitals, which ensured variability in the patient case-mix and ICU size. Moreover, in this study exploring nurse staffing costs, we used two different classification systems for workload, the NEMS and NAS, with divergent results. In addition, this study may be theoretically important because it is consistent and transparent owing to the bottom-up approach to assess nurse staffing costs.

Conclusion

A significant correlation between nurse staffing costs and assessed nursing workload in NAS and NEMS was found on merged ICU data. Our results indicate that the cost of care should be based on individual patients' nursing care needs. These can be assessed with the NAS which showed a better correlation with nurse staffing costs than did the NEMS. Nurse staffing costs per 1% NAS were quite similar in all four ICUs, which was not the case for NEMS. This study demonstrated the NAS to be an applicable tool to identify patients' nursing care needs and cost of care. Using a patient classification system such as NAS facilitates the visualisation of nurse workload and may be helpful in future planning and allocation of resources in ICUs (Miranda and Jegers, 2012; Araújo et al., 2016).

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Conflict of Interest

There are no conflicts of interest to declare.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.iccn.2018.01.007.

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