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RESEARCH ARTICLE

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Balancing workload of nurses: Linear mixed effects modelling to estimate required nursing time on surgical wards

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Abstract

Aim: Quantifying the relation between patient characteristics and care time and explaining differences in nursing time between wards.

Design: Academic hospital in the Netherlands. Six surgical wards, capacity 15–30 beds, 2012–2014.

Methods: Linear mixed effects model to study the relation between patient characteristics and care time. Estimated marginal means to estimate baseline care time and differences between wards.

Results: Nine patient characteristics significantly related to care time. Most required between 18 and 35 min extra, except "two or more IV/drip/drain" (8) and "one-on-one care" (156). Care time for minimum patient profile: 44–57 min and for average patient profile: 75–88 min. Sources of variation: nurse proficiency, patients, day-to-day variation within patients. The set of characteristics is short, simple and useful for planning and comparing workload. Explained variance up to 36%. Calculating estimated means per ward has not been done before. Nurse proficiency is an important factor.

KEYWORDS

nurse staffing, nurse workload, patient characteristics, patient classification, workload management

1 | INTRODUCTION

Health care is globally under pressure due to increasing costs (Cuckler et al., 2018) and labour shortages (World Health Organization, 2014; Zhang, Tai, Pforsich, & Lin, 2017). Healthcare costs are increasing every year and this trend is expected to continue (Cuckler et al., 2018). If this rate continues, health care may become unaffordable for lower income workers (Schieber & Nyce, 2018). Balancing workload of hospital nurses is important in this context, for several reasons. Nursing staff is a key element in delivering high-quality health care: a direct relation has been found between nurses' workload and patient outcomes (Aiken, 2014) and nurse assessed quality of care (Bogaert Van, Clarke, Willems, & Mondelaers, 2013; Van Bogaert et al., 2017). There is also a relation between workload and employee engagement and performance (Montgomery, Spanu, Baban, & Panagopoulou, 2015; Riedl & Thomas, 2019; Schaufeli & Bakker, 2004; Schaufeli, Bakker, & Van Rhenen, 2009; Van Bogaert et al., 2017) and excessive workload is a predictor for burnout (Ohue, Moriyama, & Nakaya, 2011; Spence Laschinger, Grau, Finegan, & Wilk, 2012) and absenteeism (Mudaly & Nkosi, 2015). Retaining nursing staff is important because nursing staff is increasingly scarce (World Health Organization, 2014; Zhang et al., 2017). The current healthcare workforce is also ageing rapidly (European Commission, 2011), which brings challenges in maintaining high skills

and competences in the workforce, which is essential in maintaining quality of care. Finally, workload has been shown to have an effect on nurses' intention to leave (Lacey et al., 2007; Leone et al., 2015) and on job outcomes (Van Bogaert, van Heusden, Timmermans, & Franck, 2014), both directly and as a mediating factor. High turnover of nursing staff results in higher costs for training of new nurses or using temporary staff (Twigg & Duffield, 2009; Unruh, 2008) and therefore needs to be minimized. The challenge is to support nurses in delivering high-quality care to their patients, in a way that both are cost-effective and keeps nurses healthy and engaged. Balancing nurses' workload is a key element in this challenge as it will help prevent extra costs for overstaffing a ward and prevent decreasing patient outcomes and employee engagement by understaffing a ward.

2 | BACKGROUND

One way to balance workload is with a workload management method. Several approaches are described in literature. The simplest approach is the nurse–patient ratio or nursing hours per patient day (NHPPD). There is evidence that this approach does not accurately predict workload of nurses (Upenieks, Kotlerman, Akhavan, Esser, & Ngo, 2007), since it does not take into account the different needs between patients nor the differences in experience and education level of nursing staff. Twigg (Twigg & Duffield, 2009) argues that relying on expert opinion in setting standards for workload, in their study a standard NHPPD per ward, is not optimal and recommends using a standardized patient acuity measurement.

In other methods, workload is predicted by quantifying the effect of patient characteristics or characteristics of the treatment on workload. Mueller et al. (Mueller, Lohmann, Strobl, Boldt, & Grill, 2010) tested the correlation between the Barthel index scores and Acute International Classification of Functions core sets and nurses' workload and found that 20% to 44% of perceived nurses' workload variance is explained by these scores. This suggests that patient characteristics do influence nurses' workload. That study was performed in a critical care setting and has not yet been replicated in other types of hospital wards or other environments. O Brien Pallas et al. (O'Brien-Pallas et al., 2004) have shown that the actual worked hours per patient was likely to increase for patients with a higher amount of nursing diagnoses. In Belgium, all hospitals register the Belgium Nursing Minimum Data Set (B-NMDS) to benchmark hospitals on several dimensions, including workload. Van den Heede (Van den Heede, Diya, Lesaffre, Vleugels, & Sermeus, 2008) shows that 70% of variation in nursing staff per unit is predicted by the B-NMDS item hospital type with the covariates nursing intensity and service type. They recommend using a NHPPD corrected for nursing intensity, as an alternative for working with NHPPD only. In a 2008 study (Sermeus, Delesie, Van den Heede, Diya, & Lesaffre, 2008), however, Sermeus stated that the B-NMDS nursing intensity did not necessarily give an adequate indication of required nursing time. The B-NMDS also requires extensive amount of additional registration (Myny et al., 2012). Myny et al., (2012) determined a set of 28 measurable factors expected to influence workload of nurses, of which three are recommended for incorporation in a workload management method: the number of work interruptions, the patient turnover rate and the number of mandatory registrations. It is noted that Myny et al. performed their research in Belgium, where hospitals are required by law to participate in the B-NMDS, which could explain the perceived high importance of registration on workload. The RAFAELA™ patient classification system (Rauhala & Fagerström, 2003) defines optimum levels of nursing intensity. The RAFAELA™ system consists of the Oulu Patient Classification instrument (Fagerstrom, Rainio, Rauhala, & Nojonen, 2000), a system that records daily nursing time and the Professional Assessment of Optimal Nursing Care Intensity Level questionnaire. The three are combined to measure nursing intensity. RAFAELA™ measures only the patient-related workload of nurses, other tasks are not included (Morris, MacNeela, Scott, Treacy, & Hyde, 2007). This method is not used for prospective workload management but for evaluation of past workload. For optimal and timely scheduling of nursing staff, insight in expected required nursing staff in the future is of great value. Hoi (Hoi, Ismail, Ong, & Kang, 2010) developed a workload intensity management system (WIMS) by defining 28 relevant nursing diagnoses and performing a work sampling study on nurses' activities. For each ward, the significant nursing diagnoses were determined, and for each diagnosis, the nursing time per day was determined. Hoi developed a prediction model, with a fixed component of nursing time for each patient admitted to a ward, a fixed nursing time for each occurrence of a diagnosis and a fixed time for indirect patient care. Required nursing time can be forecast based on the number of patients and the patient mix. In this study, 60%–70% of variance in nursing time was explained by these nursing diagnoses. Hoi also found that their patient dependency measurements were not correlated with nursing time.

In the current study, an approach like Hoi's has been chosen. However, instead of nursing diagnoses, the core of this method is patient characteristics defined by nurses. Estimated nurse proficiency is also included, which has not yet been described in the literature.

The development of this new workload management method has been covered in a previous study protocol (Van den Oetelaar, Van Stel, Van Rhenen, Stellato, Grolman, 2016). The protocol describes a workload management method that aims to be user-friendly, does not require much additional registration, includes all activities of nurses (not just direct patient care), is based on objective measures where possible and is suitable for staff planning purposes. The method was developed in close cooperation with nurses and ward management (head nurses) of all involved wards. It consists of three steps to calculate a workload estimate. First, a Delphi study was organized amongst senior nurses to identify patient characteristics that were expected to influence care time (manuscript submitted for review). Subsequently, a time study was done to map nurses' activities (Van den Oetelaar, Van Stel,

Stellato, Van Rhenen, Grolman, 2017) and, where applicable, to relate these activities to patients. The current article combines results of these two studies.

The aim of this article is threefold: (a) estimating patient-related required nursing time by quantifying the relation between the previously identified relevant patient characteristics and care time, (b) determining how much time is spent on patients regardless of these characteristics and (c) testing if there are differences between wards in how much time is spent on patients with the same profile of characteristics.

3 | DESIGN

This study is part of a larger study protocol for developing a workload management method for staff nurses (Van den Oetelaar et al.,2016). This workload management method is visualized in Figure 1. The Method section below briefly elaborates on the method that was chosen for the first two steps and fully describes the method for step three.

The research took place in an academic hospital in the Netherlands in 2012–2014. Six surgical wards were included (varying from 2 wards with 15 beds to 4 wards with 30 beds). The focus was on workload of nurses during the day shift, because this is the shift during which the most nursing staff is required, and most clinical nursing activities are performed.

Weekends were excluded because task mix and staffing are very different in weekends and cannot be compared with dayshifts of regular weekdays. Team leaders and students were included in the study. Ward managers were excluded because they do not participate in direct patient care or activities directly related to patient care. Activities of other types of ward staff (doctors, assistants, cleaning staff, etc.) were not considered in this study.

This study focuses on estimating care time related to patient characteristics. Other factors that may influence nurse workload such as patient turnover (Duffield et al., 2011) and unit-related characteristics such as ward layout and number of single rooms in a ward (Myny et al., 2012) and proportion of registered nurses on the ward (Duffield, Roche, & Merrick, 2006; Tourangeau, 2002) and are not considered in this phase of the study.

4 | METHOD

4.1 | Identifying patient characteristics relevant to care time

In the previously mentioned study protocol (Van den Oetelaar et al., 2016), it is assumed that workload of nurses is partly dependent on patient characteristics. A Delphi study amongst senior nurses was done to determine a set of patient characteristics that was expected to significantly i

nfluence care time (manuscript submitted for review). In the Delphi study, nurses were fully in the lead and had complete freedom to define the characteristics that they feel mattered most. Experts from all six wards took part in Delphi rounds. Ward management assigned one expert per ward to participate in the study. All participants were experienced (senior) nurses or nurse team leaders. The study consisted of four steps. Each consecutive step used the results of the previous one. The first round consisted of exploratory interviews which yielded a draft list of relevant patient characteristics. Results were shared and discussed with the Delphi group. Follow-up interviews were done to prioritize characteristics and to evaluate definitions and clarifications. This resulted in a draft checklist of relevant patient characteristics. The checklist was tested by trained nurses on all participating wards over a period of one month. After interviews with the nurses, the list was adjusted and the final version was implemented in the hospital information system (Table 1). During the time study (see below), nurses registered the patient characteristics each day for each patient.

4.2 | Time study of nurses' activities

To accurately map nurses' activities, a work sampling methodology was used. Work sampling is a useful and efficient methodology to explore work-related activities (Pelletier & Duffield, 2003). In 2007, Ampt (Ampt, Westbrook, Creswick, & Mallock, 2007) compared results of self-reported work sampling versus observational work sampling and results gave a clear preference for the observational method, hence we chose the same approach. Full details on this time study were previously published (Van den Oetelaar et al., 2017).

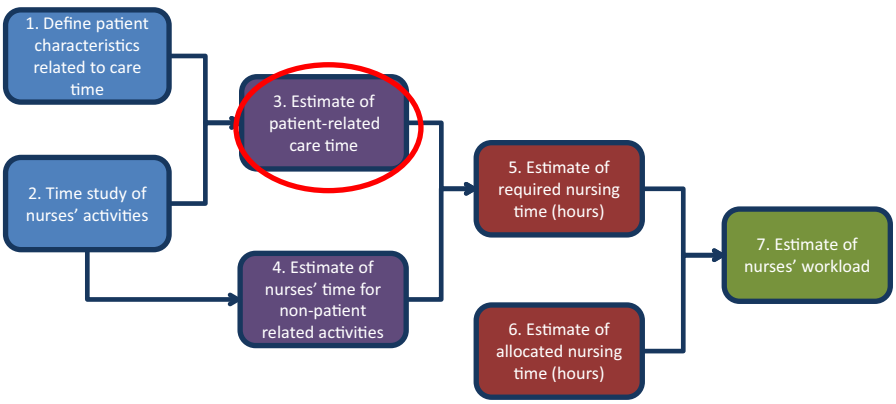

FIGURE 1 Developing a workload management method for staff nurses

TABLE 1 Patient characteristics expected to influence care time of nurses

Nr	Characteristic
1	Patient needs partial assistance bathing, mobilization
2	Patient needs full assistance bathing, mobilization or care for incontinent patient
3	Patient needs full assistance with meals, providing drip feed (portioned or by triple lumen) or TPN
4	Patient with IV, drip or drain: 2 or more
5	Patient requiring inspection or minor activity every 1 or 2 hr
6	Patient requiring inspection or minor activity several times an hour
7	Patient requiring additional psychosocial support patient or family
8	Patient with exceptional bodily proportions
9	Patient with extensive wound/fistula and/or VAC bandages
10	Patient with new tracheostoma/ileostoma/urostoma/colostoma
11	Patient with emergency admittance, complex discharge procedure, transfer from other department/hospital, extensive health education
12	Patient of other specialty or with complex additional co-morbidity
13	Patient in isolation
14	Patient unstable
15	Patient requiring one-on-one care

4.3 | Estimating patient-related care time

Care times per patient per day were derived from the time study and were combined with the daily registration of patient characteristics during the same study period. However, there is a relation between staff mix and management of workload (Duffield et al., 2006; Tourangeau, 2002) and in this study it is assumed that experienced and proficient nurses work faster than novice and student nurses and that novice nurses are not yet able to perform all tasks. If this assumption is true, then this also needs to be taken into account in staff planning. For this reason, the measurements in the time study were corrected for proficiency. In a mini-Delphi study, ward management (all head nurses with more than fifteen years experience) of all involved wards in the study was asked to define nurse categories and corresponding proficiency levels. There were six participants (one for each ward), and the mini-Delphi consisted of two rounds and two sessions to discuss results. The group defined two types of nurses: registered nurses and student nurses. Nurses' aides were not included in this study. Registered nurses were separated into fully qualified, experienced nurses and novice nurses. The group considered a registered nurse who had at least one year of experience of working in the specialty to which he or she was assigned as fully qualified and experienced. All other registered nurses were considered novice nurses in this study.

In the Netherlands, there are two types of nursing educations: one where on the job training is combined with classroom training throughout the education and one where this is separated in time. Classifying students based on this difference and on the seniority of the student resulted in four types of student nurses in our study. In total, the Delphi yielded six nurse proficiency categories. The fully qualified and experienced registered nurse was defined as the standard and set to a proficiency percentage of 100%. The proficiencies of the other five types of nurses were offset against this standard. Results can be found in Table 2.

Correction for nurse proficiency was done in the source data. In the time study, each observation of patient/date/activity was originally allocated 10 min of care time, because nurses were observed on average every ten minutes. In the corrected care time, if the nurse delivering the care was only 70% proficient, a care time of 7 min instead of 10 min would be allocated to the observation. Since the fully experienced registered nurse was chosen as the standard, all estimates for nursing time, required and allocated were translated to that reference. This means that the times spent by less experienced nursing staff were reduced, in line with the assumption that a fully experienced registered nurse would have spent less time on the same task.

Linear mixed effects models (Hedeker & Gibbons, 2006) were used to determine the significance of the patient characteristics in relation to care time and to estimate the additional care time per significant characteristic. Since most patients were admitted for more than one day, care time was measured more than once for most patients; linear mixed effects models are appropriate for analysing such multilevel data. A mixed model gives insight into the variability of care time within the length of stay of a patient, but also the

TABLE 2 Proficiency of nurses: expert nurses' estimates

Type of nurse	Average proficiency %
Registered Nurse ≥ 1 year experience in specialty of department they are assigned to	100%
Registered Nurse < 1 year experience in specialty of department they are assigned to	82%
Student nurse (working student 3rd or 4th year)	68%
Student nurse (fulltime student 3rd or 4th year)	47%
Student nurse (working student 1st or 2nd year)	40%
Student nurse (fulltime student 1st or 2nd year)	Not applicable

variability of care time between patients. In the models, the ward and the 15 patient characteristics were included as fixed effects. A random intercept per patient was included in the models to adjust for clustering of measurements within patients.

The linear mixed effects modelling was done twice: model 1 used the original care times and model 2 used the care times corrected for nurse proficiency. The percentage of variance in care time explained by the mixed models (R^2) was estimated using the method described by LaHuis et al.(LaHuis, Hartman, Hakoyama, & Clark, 2014).

In addition to care time related to patient characteristics, it is also assumed that there is a "baseline care time". When a patient is admitted to a ward, nurses will always spend a certain amount of care time on this patient, regardless of the reason for admission (time that is spent handing out meals, having a chat or tidying up). In this study, it is assumed that there is always a baseline amount of care that is provided to a patient when admitted to a ward, as also suggested by Hoi (Hoi et al., 2010).

To estimate the baseline care time for each ward, estimated means were derived from the linear mixed effects model for a patient profile where none of the characteristics are present.

Also, estimated means were derived for a patient with the average mix of the patient characteristics (as observed over all wards during our study). Differences between the wards were tested using Sidák's adjustment for multiple testing.

Several interactions were considered to be included in the study (e.g. between bodily proportions of patient and assistance with bathing and mobilization and between isolation measures and inspection or minor activity several times an hour), but these did not occur often enough to generate sufficient observations. Statistical significance level was set to 0.01. All analyses were performed in SPSS version 21.

5 | ETHICS

The study guaranteed the privacy of involved staff and patients. Only the lead researcher has access to the source data. Data have been processed in such a way that nothing can be traced back to specific individuals. The study protocol was submitted to the medical ethical review board of the study hospital and was approved, protocol number 14-165/C.

6 | RESULTS

6.1 | Relation between patient characteristics and care time

After data validation, registration of characteristic 14, "Patient unstable," turned out to be incorrect and incomplete. It was not possible to retrospectively correct the data in a reliable manner, and therefore, this variable was excluded from further analysis.

Theoretically, there were 2,224 possible observations of patient characteristic and care time during the observation sample period (number of patient days included in the study). Patient characteristics checklists were not always completed, for example in situations when the patient spent most of the dayshift in surgery. In addition, the registration equipment failed several times (download failure) and sometimes patient identification was not registered.

Incomplete checklists and registration failures resulted in missing data for 466 observations, as described in Table 3. 1758 observations, from 625 patients, were available for analysis. The results of the analysis of the observed care times can be found in Table 4.

In Model 1, nine characteristics were significantly related to care time: characteristics 1, 2, 3, 7, 8, 9, 10, 13 and 14. The model explained 40% of variation in observed care times between patients and 25% of variation within patients (day-to-day variation for a patient). The results of the model for care times corrected for nurse proficiency, Model 2, can be found in Table 5

In Model 2, nine characteristics were also significantly related to care time (1, 2, 3, 4, 7, 9, 10, 13 and 14). Note that "Patient with IV, drip or drain: 2 or more" is now significant and that "Patient with exceptional bodily proportions" is no longer significant.

In the second model, 36% of variation in corrected care times between patients is explained by the model and 22% of variation within patients (day-to-day variation for a patient).

6.2 | Estimated means

The estimated means were calculated per ward, for a patient profile where none of the patient characteristics were present (minimum profile) and for an average patient profile. Estimated means were calculated for the original care times (Model 1) and the corrected care times (Model 2). Results can be found in Table 6.

Using the original care times, we see a remarkable difference: ward 6 has a much higher mean than the other wards. For example, care times in Model 1 for patients with an average patient profile range between 98–104 for wards 1–5, but ward 6 has an average care time of 132, a statistically significant difference with all other departments (all *P*-values < .01). The same significant difference is found in Model 1 for a patient profile where none of the characteristics in the model apply: care time for wards 1–5 ranges from 57–64 while care time for ward 6 is 91. This would mean that the nursing staff of ward 6 spend on average much more time caring for the same type of patient. However, after correction for nurse proficiency, the difference in care time between wards is considerably smaller (Model 2) and no longer statistically significant. Using the corrected care times, the mean care time spent on a patient for whom none of the patient characteristics were present was between 44–57 min per patient (on average 51 min). We consider this the baseline care time.

7 | DISCUSSION

7.1 | Findings

The relation between previously identified patient characteristics and care time was quantified, and nine patient characteristics were

TABLE 3 Missing data

Theoretical maximum observations per characteristic (amount of patient days included the time study period)	2,224
Missing data due to equipment failure (e.g. failure of scanning equipment)	56
Missing data due to patient identification issues (e.g. due to registration omission or error)	75
Missing observation list	335
Actual maximum observations per characteristic (amount of times a combined observation of patient/date/observation list was registered)	1,758

TABLE 4 Linear mixed effects Model 1 (original care time)

#	Patient characteristic	# Observations	*p*-value	Estimate (minutes)	Std. Error	99% Confidence Interval	
						Lower Bound	Upper Bound
1	Patient needs partial assistance bathing, mobilization	843	.000	20.9	3.9	10.9	30.9
2	Patient needs full assistance bathing, mobilization or care for incontinent patient	371	.000	47.5	5.1	34.2	60.7
3	Patient needs full assistance with meals, providing drip feed (portioned or by triple lumen) or TPN	182	.000	48.4	5.8	33.5	63.4
4	Patient with IV, drip or drain: 2 or more	516	.014	8.9	3.6	−0.5	18.2
5	Patient requiring inspection or minor activity every 1 or 2 hr	518	.180	−4.9	3.7	−14.4	4.5
6	Patient requiring inspection or minor activity several times an hour	61	.735	2.8	8.3	−18.5	24.1
7	Patient requiring additional psychosocial support patient or family	134	.000	24.9	6.0	9.5	40.3
8	Patient with exceptional bodily proportions	17	.002	47.8	15.6	7.7	88.0
9	Patient with extensive wound/fistula and/or VAC bandages	79	.000	29.0	7.5	9.5	48.5
10	Patient with new tracheostoma/ileostoma/urostoma/colostoma	79	.000	30.2	8.1	9.4	51.1
11	Patient with emergency admittance, complex discharge procedure, transfer from other department/hospital, extensive health education	24	.703	4.9	12.8	−28.1	37.9
12	Patient of other specialty or with complex additional co-morbidity	19	.966	0.6	13.9	−35.3	36.5
13	Patient in isolation	165	.000	29.0	7.1	10.7	47.2
14	Patient requiring one-on-one care	27	.000	177.9	13.3	143.5	212.3

found to be significantly related to care time delivered by nurses. The significant characteristics were "partial assistance bathing, mobilization," "full assistance bathing, mobilization, care for incontinent patient," "full assistance meals, dripfeed, TPN," "two or more IV/drip/drain," "psychosocial support," "extensive wound care, fistula, VAC bandages," "new stoma," "isolation measures" or "one-on-one care." Most characteristics required an additional 18–35 min on average, with the exception of "two or more IV/drip/drain" (8 min) and "one-on-one care" (156 min). Data were corrected for nurse proficiency. The mean daily care time for patients with a profile where none of the characteristics in our study are present was between 44–57 min. Mean daily care time for patients with an average patient profile (of the patient characteristics in our study) was between 75–88 min. Major sources of variation between wards were proficiency of nurses, patients and day-to-day variation within patients. The models explained more variance (R^2) between patients (36 and 40% for corrected and uncorrected care times, respectively) than within (day-to-day variation for a patient, 22 and 25%, respectively).

One-on-one care is technically not a patient characteristic, but was added to the checklist as a way to indicate that one nurse was

TABLE 5 Linear mixed effects Model 2 (care times corrected for nurse proficiency)

#	Patient characteristic	# Observations	*p*-value	Estimate (minutes)	Std. Error	99% Confidence Interval	
						Lower Bound	Upper Bound
1	Patient needs partial assistance bathing, mobilization	843	.000	18.0	3.2	9.8	26.3
2	Patient needs full assistance bathing, mobilization or care for incontinent patient	371	.000	34.4	4.2	23.6	45.3
3	Patient needs full assistance with meals, providing drip feed (portioned or by triple lumen) or TPN	182	.000	30.8	4.8	18.5	43.1
4	Patient with IV, drip or drain: 2 or more	516	.006	8.1	3.0	0.5	15.8
5	Patient requiring inspection or minor activity every 1 or 2 hr	518	.618	−1.5	3.0	−9.3	6.3
6	Patient requiring inspection or minor activity several times an hour	61	.311	6.9	6.8	−10.6	24.4
7	Patient requiring additional psychosocial support patient or family	134	.000	20.0	4.9	7.3	32.6
8	Patient with exceptional bodily proportions	17	.040	26.4	12.8	−6.7	59.4
9	Patient with extensive wound/fistula and/or VAC bandages	79	.000	22.7	6.2	6.7	38.7
10	Patient with new tracheostoma/ileostoma/urostoma/colostoma	79	.002	20.2	6.6	3.1	37.4
11	Patient with emergency admittance, complex discharge procedure, transfer from other department/hospital, extensive health education	24	.683	4.3	10.5	−22.8	31.4
12	Patient of other specialty or with complex additional co-morbidity	19	.888	1.6	11.4	−27.9	31.1
13	Patient in isolation	165	.000	20.9	5.8	5.9	35.8
14	Patient requiring one-on-one care	27	.000	156.3	10.9	128.1	184.5

TABLE 6 Estimated means

Ward	Model 1: original data		Model 2: data corrected for nurse proficiency	
	Mean (min) Patient average characteristics	Mean (min) Patient no characteristics	Mean (min) Patient average characteristics	Mean (min) Patient no characteristics
1	104	63	85	54
2	103	62	80	49
3	104	63	85	54
4	98	57	75	44
5	104	64	77	46
6	132	91	88	57

busy during the entire shift with caring for one specific patient. A previous study (Van den Oetelaar et al., 2017) showed that the nurses spent 40%–56% of their working day on activities that can be directly related to one patient. On the wards where one-on-one care was most often registered (wards 2, 5 and 6) this amounts to between 192–227 min per dayshift of 480 min. If the baseline care time of 51 min per patient is subtracted, the result is roughly in line with the average care time of the characteristic one-on-one care that was found before correction for nurse proficiency: 156 min. The regular small inspections/activities turned out not to be significant to care time. Perhaps this is the case because these are done when nurses are in the room with the patient anyway, for other, more time consuming, activities. "Patient with IV, drip or drain: 2 or more" was significant in the corrected times, but not in the uncorrected. "Patient with exceptional bodily proportions" turned out to be not significant after all, which is likely explained by the small number of observations for this characteristic (17 observations).

In the estimated means for unadjusted care times, ward 6 stood out; analyses for both patient profiles indicated that significantly more time was spent for the same type of patient on this ward than on other wards. Ward 6 works with more student nurses than other wards and correcting for nurse proficiency eliminated this difference.

The baseline care time indicates that there is quite a lot of time spent on activities that are patient related, but not explained by the patient characteristics examined: 44–57 min per patient. This can be time for example for preparing (standard) medication, reporting or speaking to a patient's family. Baseline care time is approximately 45 min to an hour, which is longer than the extra half hour spent on patients with an "average" set of patient characteristics. That means that activities that are considered to be part of baseline care take more time than activities related to the patient characteristics in our study. For the expert nurses in our Delphi group, apparently these activities did not come to mind when considering what leads to additional care time, but they do represent a large proportion of the care time spent on patients. More research is needed on the baseline care time, to understand better if relevant patient characteristics have been missed.

7.2 | Comparison

There is limited literature available that quantifies the relation between patient characteristics and care time in minutes or hours in a non-acute hospital setting.

Myny (Myny et al., 2010) found six groups of activities to be most time consuming: hygiene, urinary and bowel care, emotional support, wound care, education and feeding. Although the definition of activity groups is not exactly the same, all activity groups except education are also significant in our study. Myny uses the Belgian Nursing Minimum Dataset as a basis. Collecting this dataset is mandatory in Belgium, so data are available for all Belgian hospitals, but this is not the case in other countries.

Perroca's patient classification system (Perroca, 2011) covers 9 care areas: care process planning and coordination; investigation and monitoring; personal hygiene and eliminations; nutrition and hydration; locomotion or activity; therapeutics; emotional support; health education; skin integrity. Perroca's study does not mention the definitions of the care areas so possibility for comparison is limited.

Van Oostveen, Vermeulen, Gouma, Bakker, and Ubbink (2013) studied 17 patient characteristics expected to influence the cost of care. Seven of these turned out to be significantly associated to cost of care: age, number of complications, ASA-class, nutritional status, admission type, number of medications during hospitalization and surgical specialty. Van Oostveen also found that isolation measures were not significantly related to care costs; in our study, this is a significant characteristic to care time. Our study aim did not primarily consider costs, however, but focuses on balancing nurses' workload. Some patient characteristics may correlate with costs but do not necessarily correlate with care time, for example number of medications.

Hoi et al., (2010) found 10 nursing diagnoses that were significantly related to care time. These diagnoses were related to nutrition, mobility, skin integrity, confusion, incontinence and tissue perfusion. The definitions are different from ours and cannot be compared exactly. However, Hoi did find that diagnosis related to tissue perfusion gave the most extra care time per patient, followed by confusion, nutrition and mobility. The extra time varied considerably between disciplines. This is in line with our findings.

Our study describes several characteristics that have not been studied before for their relation to care time or nurses' workload. For example, a characteristic called bodily proportions of the patient was introduced. In other studies, such as Myny et al., (2014), BMI is often included. However, even if a patient's BMI is normal, the bodily proportions can result in extra care time: for example, when helping a very tall (and thus heavy) patient with bathing.

One-on-one care is a new concept in the context of patient classification. In previous studies, this has not been mentioned or described. Nurses indicated that if many different characteristics apply for one patient, the total care time is higher than you would expect based on the sum of the care times for the separate characteristics.

7.3 | Study strengths and limitations

Nurses had complete freedom in determining a set of patient characteristics that they believed influence care time the most. This resulted in a new set of characteristics, several of which have not been studied before. The effects of patient characteristics on care time were quantified by work sampling over a relatively long study period of 15 dayshifts. Data were analysed using a multilevel approach, which is rare in this field of study. Data were corrected for estimated nurse proficiency, which has not been done before and proved to be an important factor to include in the analysis. New concepts "baseline care time" and "one-on-one care" were defined and quantified.

Our study was set in an academic hospital, which makes it uncertain whether the study results can be readily applied to different settings, such as general hospitals. Nurses' activities and patient mix in general hospitals are likely to be different than in academic hospitals. The study is based on a random sample of nurses' activities, which gives an estimate of true care time. Activities were sampled approximately every ten minutes, which may not properly reflect reality, although overall there were a large number of observations in the study. The number of observations per characteristic is limited for some characteristics, leading to uncertain estimates. During the time study, 21% of the observation lists were not filled in. The missing lists were randomly distributed across the time study days, patients and across departments, so it is assumed that the missing data did not affect the study results. This study focuses on the effect of patient characteristics on care time and does not take into account other known factors that influence nursing time (such as patient turnover), unit-related characteristics (such as ward layout and number of single rooms in a ward) or ward team dynamics.

Nurses in the study indicated that patient characteristic "Patient unstable" was likely to be relevant to care time. In their systematic

review on the use of early warning score systems in hospitalized patients, Smith et al., (2014) found that an increasing early warning score was associated with more frequent observations by nurses. Since the registration of early warning scores could not be included in this study, further research on this characteristic in the context of nurse workload is recommended.

Introducing a nurse proficiency estimate in the workload equation proved to be a valuable addition, since our findings indicated that leaving it out may lead to over- or underestimation of workload. In our study, proficiency was estimated by head nurses. The analysis focused on patient-level variation in care time and measured on a daily basis. Work sampling was used to determine care time provided to the patient. Another way to measure the proficiency of nurses would be to keep track of the actual exact time spent on each activity, calculate an estimate per activity per type of nurse and derive the proficiency percentage from these estimates. However, since there were 6 types of nurses and 24 activity groups in the study, this approach would have required a much larger sample size and a more accurate measurement of time spent on an activity than work sampling every 10 min. For practical reasons (costs, registration), this was not possible, and the choice was made to have ward management estimate nurse proficiency instead. In another study setting, measuring proficiency may well be possible.

7.4 | Interpretation

The set of relevant patient characteristics that was determined is short, easy to use and gives an indication of which patient characteristics are most relevant to care time and to what extent. Results can be used for planning purposes and to compare workload between hospital wards. Our set of characteristics explained 36% of variation in care time between patients and 22% of the day-to-day variation in care time within patients. Although expert nurses determined this set with complete freedom, the explained variation is relatively low. This means that other factors influence care time and those factors may be less obviously related to care time for the expert nurses. Certain additional patient characteristics may have been missed in our study. In the time study (van den Oetelaar et al., 2017), results showed that a substantial part of direct patient care consists of administration and reporting (26%) and communication with patient or family (12%). Certain medical or patient conditions may require additional registration, for example risk assessments on malnutrition or falling, or more communication, for example unstable condition of the patient. These interactions were not included in this study. However, the unexplained variance may also be related to more subjective variables such as the personality of the patient or the nurse. For example, some patients are likely to demand or get more care time than others, regardless of their condition. Personal connection between patient and caregivers may also be a factor of interest. Also, frequently studied variables such as the number of work interruptions (McGillis Hall, Pedersen, & Fairley, 2010; Myny et al., 2012) and patient turnover (Duffield et al., 2011; Myny et al., 2011, 2012) and ward-related factors such as available support staff or logistic workers and ward layout (Myny et al., 2012) may be factors of importance but were not included in this study. Duffield (Duffield et al., 2011) reports that the task most frequently reported as left undone is comforting and talking to patients. When workload is acceptable, there may be time for this activity, which may also explain part of the unexplained variance in care time. Another explanation could be that the study is set in an academic hospital, where multidisciplinary care is common and doctors of several different specialties may be involved in taking care of an individual patient. Multidisciplinary care is not always organized in an optimal way. For example, doctors of different specialties may visit the patient at different times of the day. Each visit may require patient-related activities such as wound inspection and consequently care time of nurses to facilitate this. So, organizational characteristics such as these can also have an impact on care time of nurses. Further research in that area is recommended.

Calculating the estimated means per ward for a certain patient profile gives additional information on the differences between wards. This method has not been described in literature before.

8 | CONCLUSION

In short, the conclusion is that our model is useful to gain insight in differences in required care time per patient and to identify differences in care time between wards, but our model does not explain all variation in care time. Further study other factors that influence care time is recommended. It is stressed that nurse proficiency is an important factor in the workload equation, since leaving it out may distort results and lead to false assumptions.

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CONFLICT OF INTEREST

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

AUTHOR CONTRIBUTIONS

WO, WR, WG, RS: Made substantial contributions to conception and design, acquisition of data, analysis and interpretation of data; Involved in drafting the manuscript or revising it critically

for important intellectual content; Given final approval of the version to be published. Each author should have participated sufficiently in the work to take public responsibility for appropriate portions of the content; Agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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