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The association between nurse staffing and inpatient mortality: A shift-level retrospective longitudinal study

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ABSTRACT

Background: Worldwide, hospitals face pressure to reduce costs. Some respond by working with a reduced number of nurses or less qualified nursing staff.
Objective: This study aims at examining the relationship between mortality and patient exposure to shifts with low or high nurse staffing.
Methods: This longitudinal study used routine shift-, unit-, and patient-level data for three years (2015–2017) from one Swiss university hospital. Data from 55 units, 79,893 adult inpatients and 3646 nurses (2670 registered nurses, 438 licensed practical nurses, and 538 unlicensed and administrative personnel) were analyzed. After developing a staffing model to identify high- and low-staffed shifts, we fitted logistic regression models to explore associations between nurse staffing and mortality.
Results: Exposure to shifts with high levels of registered nurses had lower odds of mortality by 8.7% [odds ratio 0.91 95% CI 0.89–0.93]. Conversely, low staffing was associated with higher odds of mortality by 10% [odds ratio 1.10 95% CI 1.07–1.13]. The associations between mortality and staffing by other groups was less clear. For example, both high and low staffing of unlicensed and administrative personnel were associated with higher mortality, respectively 1.03 [95% CI 1.01–1.04] and 1.04 [95% CI 1.03–1.06].
Discussion and implications: This patient-level longitudinal study suggests a relationship between registered nurses staffing levels and mortality. Higher levels of registered nurses positively impact patient outcome (i.e. lower odds of mortality) and lower levels negatively (i.e. higher odds of mortality). Contributions of the three other groups to patient safety is unclear from these results. Therefore, substitution of either group for registered nurses is not recommended.

What is already known

- For more than three decades, researchers have investigated the complex relationship between nurse staffing and quality of care.
- The majority of studies were conducted in the US and used a cross-sectional design; a design that does not allow causal inference.
- It is not clear from previous studies whether observed improvements in patient outcomes resulted from increased nurse staffing or from systemic differences between high- and low-performing hospitals.

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What this paper adds

- By its rich granularity, our study contributes to the understanding of the association between nurse staffing and patient mortality, looks at three groups of nurses as independent variables and explores high/low nurse levels on different shifts and weekdays/weekends.
- By reducing confounding from unmeasured differences between different centers (e.g. different support infrastructures, leadership and work environment factors), the study adds to the evidence of a potentially causal link regarding the hypothesized relationship between the number of registered nurses and patient mortality.
- The findings reported here suggest that even in a healthcare system offering high quality of care, with relatively high staffing levels in comparison to other European countries patients still benefit from high registered nurse staffed shifts. Furthermore, we found exposure to low registered nurse staffed shifts increasing the risk of mortality.

1. Introduction

Hospitals are challenged to provide nurse staffing levels adequate to ensure patient safety while maintaining reasonable costs. For decades, the association between nurse staffing and patient outcomes has been of interest. As a result, nurse staffing and/or poor skill mixes have been correlated, for example, with falls, nosocomial infections, and various complications linked more specifically to nursing care (Driscoll et al., 2018; Kane et al., 2007). One of the most commonly analysed relationships is the one with mortality clearly defined and available in routine data (Van den Heede et al., 2007).

The key driver of nurse workload variation is patient need, which fluctuates during the day and varies between units. It depends largely on the patient-to-nurse ratio, which changes in turn with patient turnover (admissions, discharges and transfers between units) (Blay et al., 2017). However, turnover affects nurse workload not only in terms of patient numbers but also regarding the tasks associated with each admission and discharge (Aiken et al., 2013; Jennings et al., 2013). Both high patient turnover and high patient-to-nurse ratios are linked to a higher likelihood of hospital-related mortality (Driscoll et al., 2018; Kane et al., 2007).

Although many studies have shown an association between nurse staffing and patient mortality, our understanding of that association remains incomplete. Several reasons have been described, for example, the use of aggregated data over time or the fact that most studies use cross-sectional designs, which preclude causal inferences (Griffiths et al., 2016; Twigg et al., 2011). Further, by aggregating data at the hospital level or using mean patient-to-nurse ratios, researchers have commonly ignored variation between units, between patients, and over time. Not accounting for this variation might have diluted the association of nurse staffing and patient outcomes. Similarly, previous studies could not estimate individual patient exposure to nurse staffing (Twigg et al., 2011). This lack of detail limited the understanding of the association between nurse staffing and patient mortality.

As nurse-patient relationships occur on an individual level, exposure to nurse staffing varies between patients on different shifts, days and units. To date, few nurse staffing studies have considered some or all of the following elements: (1) longitudinal designs; (2) shift-, unit-, and patient-level analysis; and (3) the contributions of nursing staff other than registered nurses (RNs) as independent variables (Griffiths et al., 2018; Needleman et al., 2011; Needleman et al., 2019).

In a recent study, we analyzed fluctuations in patient count and nursing staff longitudinally at 30-minute intervals, 24 h per day over a period of three years in a large University Hospital (Musy et al., 2020). Our findings indicated that, viewed on its own, the considerable variability of the patient count throughout the day challenges the nursing staff to provide safe, reliable care. In numerous other ways, that study's descriptive analysis detected and described variability patterns for nurses, patients, and patient-to-nurse ratios. For the current study, we have linked the same staffing data to patient outcomes to explore mortality based on patients' exposure to shifts with low *and* high numbers of RNs and/or nursing assistants. Using a novel approach which models the deviation of the long-term shift level nurse staffing, the analysis provides a perspective on what optimal staffing levels might constitute. Furthermore, unlike previous studies, we will also examine the effects of staffing between shifts and between weekdays and weekends.

2. Methods

2.1. Study design and setting

This is a retrospective, observational study using routinely collected data from the one of the five University Hospital in Switzerland, which treats around 48,000 inpatients annually. Data of three years (2015–2017) were available for all departments, excluding *Paediatrics* and *Maternity & Gynaecology* as those populations have different nursing care requirements and complexities. The final sample contained 55 inpatient units with complete data for the full collection period.

2.2. Participants

2.2.1. Patients

Our inclusion criteria targeted the following patients: 1) inpatients; 2) adults (18 years old or older); 3) had no part of their stay on any units not included in the study; 4) had no emergency stays after their first day; and 5) whose records included complete demographic and hospitalization information (see details in Fig. 1).

2.2.2. Nurses

To select our nurse sample, we divided the entire staff providing direct or indirect nursing care into three groups: 1) *registered nurses* (RNs), including those in supervisory positions (3–4 years of tertiary/professional or university-based education); 2) *licensed practical nurses* (LPNs) (3 years of secondary-level professional training); and 3) *others*, including unlicensed staff, for example, nursing aides (minimal education/training) and administrative personnel. For further details, see Musy et al. (2020).

2.3. Data sources and variables

We collected data from two sources: (1) The tacs® nurse staffing system, which records information on nurses' direct and indirect care, patient turnover, working hours and unit: and (2) medical discharge data, which includes patient demographics, admission and discharge details, diagnoses, and mortality. For further details on the merging process and variables relating to these data, see Musy et al. (2020). In the final dataset, all patients, nurses and units were deidentified, leaving only department names.

2.3.1. Nurse staffing per unit-shift

For this analysis, the number of nurses on key time points corresponding to the night, morning, and evening shift were used. This decision was made in order to avoid the high peaks of nurses during shift changes, thereby representing the number

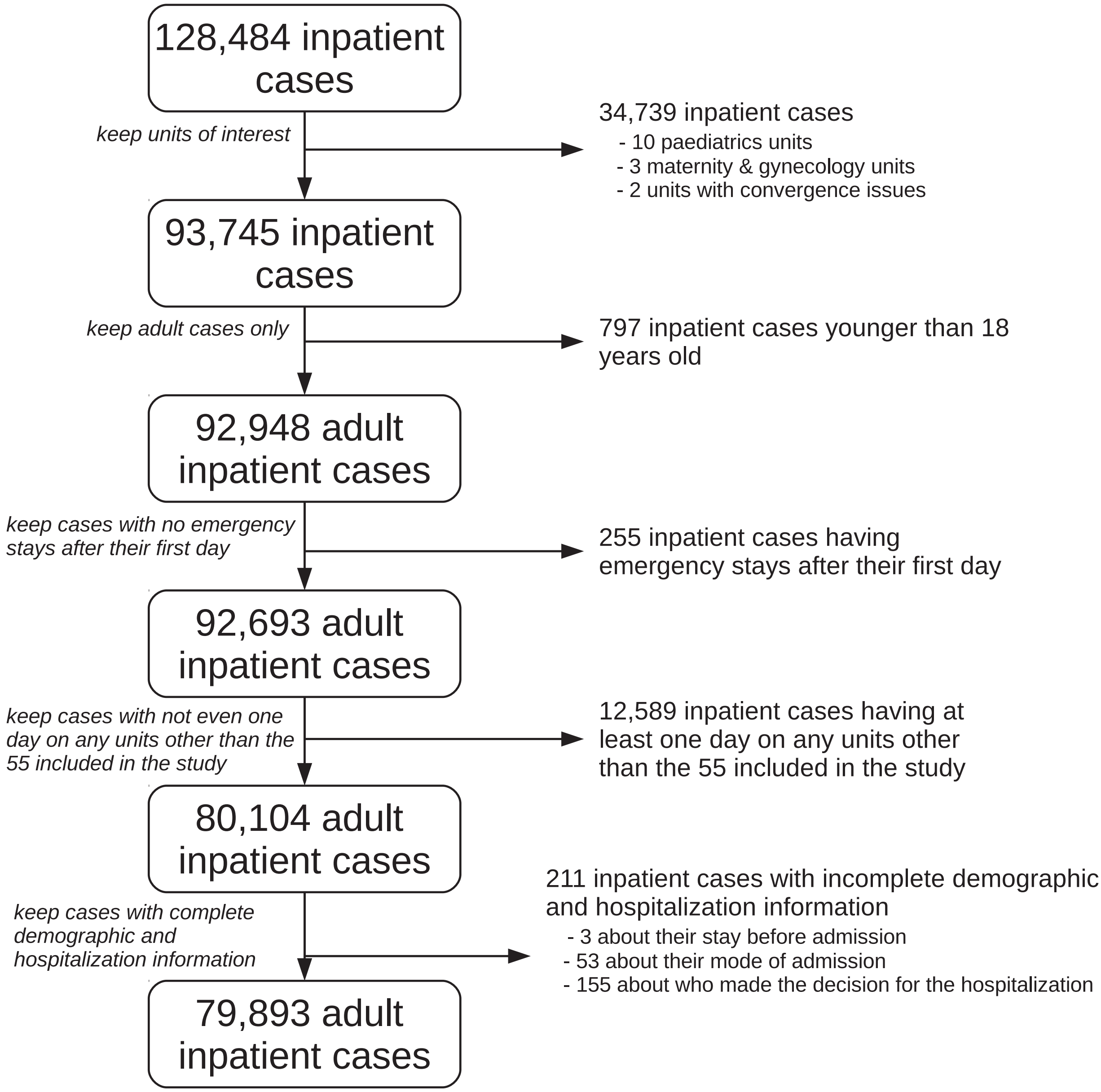

Fig. 1. Overview of the effects of patient inclusion criteria, selecting for adult inpatient cases with complete staffing plus complete demographic information.

of nurses actually present on the shift (for further details see Musy et al. (2020)).

2.3.2. Patient counts and turnover

We computed the number of patients present for each shift for each unit across the full three years of data. The number of admissions, discharges, and transfers (in and out) were calculated for every unit at 30 min intervals. In order to represent the amount of patient turnover for a full shift, the patient turnover values were summed individually for each shift and unit as follows: (1) night shift (22:30–06:00); (2) morning shift (06:30–14:00); and (3) Evening shift (14:30–22:00). As units have various shift times, we decided to choose key time points (02:00, 10:00, and 18:00) representing the middle of the shift, then to treat every shift as an 8-hour period. The results represented all patient turnover for each shift, day and unit. Admissions and inbound transfers were summed as entries, discharges and outbound transfers as exits.

2.3.3. Patient characteristics

We used the following patient characteristics to adjust for mortality risk: (1) age (in years) at admission; (2) gender; (3) residence before hospital admission (home, home with home care, other hospital (acute care), and other); (4) type of admission (emergency, planned, transfer within 24 h, and other); (5) decision-maker regarding admission (own volition/relatives, rescue service (police, ambulance), physician, and other); (6) stay in *Intensive Care* – presented two ways, i.e., hours spent in *Intensive Care* and dichotomized as a yes/no variable; (7) stay in emergency (presented in the same two ways as the stay in *Intensive Care)*; (8) length of overall hospital stay; (9) number of transfers within the hospital; and 10) number of ICD-10-GM diagnoses (up to 50 were possible). ICD-10-GM stands for the “International Statistical Classification Of Diseases And Related Health Problems, 10th revision, German Modification” and is used in Switzerland to encode diagnosis. Elixhauser comorbidity indices – calculated for the ICD-10-GM codes using the weighted summary score developed by van Walraven – proved superior to simple co-morbidity counts (Thompson et al., 2015). They have shown to improve the predictions of mortality, further details can be found elsewhere (Elixhauser et al., 1998; Menendez et al., 2014; van Walraven et al., 2009).

2.3.4. Inpatient mortality

At hospital discharge, each patient's vital status (deceased or alive) was recorded, allowing creation of a binary variable: for our purposes, each deceased patient was encoded with '1′; otherwise, '0′.

2.4. Statistical analyses

All statistical analyses were conducted using R, version 3.5.3 for Mac OS and Linux (R Core Team, 2017).

2.4.1. Descriptive analysis

For each department, unit-, daily-, and shift-level median and interquartile ranges were calculated for the raw numbers and patient-to-nurse ratios regarding patients, RNs, LPNs, and Others. As we expected dependencies between the three nurse groups, we calculated unit- and shift-level Spearman's rank correlation coefficients (results presented in Online supplemental file 1). The strongest positive correlation ($\rho > 0.50$) was observed between RNs and Others for mornings; LPNs and Others had the strongest negative correlation at night ($\rho < -0.80$). Based on these dependencies, we chose a multivariate model for nurse staffing. Finally, characteristics of patients who survived and those who died were compared using Cohen's d (Austin, 2011).

2.4.2. Mortality model

A two-step approach was used. First, for each of the 55 units, based on the number of patients, the shift (morning = reference), the day of the week (Monday = reference), the number of entries and exits, and the median Elixhauser index value per weekday and shift, a multivariate Poisson model was used to calculate the expected number of nurses (RNs, LPNs, and Others) on duty. To calculate the observed-over-expected ratio (O/E) for each shift, unit, day of the week, and group of nurses, we divided the actual number of nurses present (observed) by the expected value. An O/E below 1 indicates fewer nurses present than expected; an O/E above 1 indicates more.

The main advantage of the O/E ratio is that, because it is based on unit characteristics, a chosen threshold is comparable across units. We used it to estimate low or high staffing shifts. As no consensus exists on what is low or high, we chose arbitrary cut-offs of O/E median plus half for high staff and minus half for low staff, which was also used in our descriptive analysis (Musy et al., 2020).

For every patient's stay, cumulative counts of high and low RNs, LPNs, and Others were computed for each unit, day type (weekday/weekend) and shift, leading to 6 staffing variables. To explore associations with mortality, we applied logistic regression to every patient's demographics, clinical data, and those 6 variables. We determined the best fitting model by backward selecting variables based on the Akaike information criterion (i.e. as low as possible) and the variable's contribution to the model quality (i.e., decreasing residual deviance). The variables with the lowest contribution to the model quality were dropped until an appropriate model was found. As a sensitivity analysis, we developed two other models for the first 5 days of each patient stay (using similar thresholds to those used in previous longitudinal studies) (Griffiths et al., 2018; Needleman et al., 2011, 2019) and for the highly detailed 36 staffing variables (high and low for the three nurse groups for the three shifts and for weekday/weekend).

2.5. Ethical considerations

Based on Swiss legislation on research with humans, data acquisition from the Inselspital (University Hospital of Bern) for this type of research was outside the purview of the Cantonal Ethics Commission of Bern (Req-2016–00618). All data involving patients, nurses, and units were deidentified.

3. Results

3.1. Participants

Fig. 1 shows the number of cases corresponding to each patient criterion. Of 128,484 inpatient cases, 79,893 (62.2%) were finally included, along with 3646 nurses (2670 RNs (73.2%), 438 LPNs (12.0%), and 538 Others (14.8%)) across 55 units.

3.2. Descriptive analysis

3.2.1. Overview

Table 1 provides an overview of the departments and units included (see also Online supplemental file 1 for each unit). The median number of nurses per unit decreased through the day (highest in the morning and lowest at night), with a corresponding increase in the patient-to-nurse ratio. Patient-to-RN ratios ranged between 1.3 and 2.2, between 2.0 and 3.7, and between 3.7 and 11.0 respectively for the morning, afternoon, and night shifts. The lowest patient-to-nurse ratios were observed in *Intensive Care*, with values approaching 1.0. LPNs and Others had a median of 0.0–1.0 nurse for almost all shifts; therefore, the patient-to-nurse ratio ranged between indeterminate (denominator of 0.0 nurses) and 10.5.

3.2.2. Comparison between patients' demographics variables of alive and mortality cohort

Table 2 shows the results of our comparison between patients who were discharged alive ($n = 77{,}663$) and those who died ($n = 2230$) during their hospitalization. The number of deceased patients represents 2.9% of the total patient population ($n = 79{,}893$). Large differences were observed for the type of admission, stay in ICU (yes/no), number of diagnosis, and Elixhauser comorbidity score. In comparison to patients discharged alive, those who died were on average 10 years older, were admitted predominantly (70%) from emergency, stayed on average two days longer in hospital, had around twice the mean number of diagnoses, stayed longer in ICU, and had double the mean Elixhauser comorbidity score. Patients who died were overall exposed to more shifts with low nurse staffing (0.69) than patients alive (0.44) at discharge.

3.3. Mortality predictive model

The staffing models with detailed unit-level coefficients are displayed in Online supplemental file 2. Fig. 2 displays the percentages of low and high shifts for each department and nurse group (RNs, LPNs, Others). The percentages ranged from 0.9 to 9.2% and 5.7–16.2% for RNs for low and high, respectively. For LPNs, it ranges from 4 to 14.4% and 10.8–21.6% for low and high, respectively. Finally, for Others, both have similar ranges from 8.1% to 17.8%. Online supplemental file 3 displayed the same results on unit- and shift-level.

The mortality model in Table 3 presents only the staffing variables (see Online supplemental file 4 for patients' demographics). High RN staffing was associated with lower odds of mortality (−8.7%), whereas low staffing was associated with higher odds of mortality (+10%). Findings for LPNs and Others were not consistent. However, both high and low LPN staffing were associated

Table 1
Median and interquartile ranges for the numbers of nurses and patients, as well as unit- and shift-level patient-to-nurse ratios for each department.

	Units	Shifts	PRR	PLR	POR	Patients (N)
Internal Medicine	6	Morning	2.0 [1.6–2.5]	6.0 [0.0–11.0]	8.2 [5.0–13.0]	13.0 [11.0–16.0]
		Evening	3.5 [2.5–5.0]	0.0 [0.0–10.0]	3.7 [0.0–12.0]	13.0 [11.0–15.0]
		Night	9.0 [6.0–12.0]	0.0 [0.0–0.0]	0.0 [0.0–0.0]	13.0 [11.0–16.0]
Cardiology & Cardiovascular Surgery	11	Morning	1.3 [1.0–1.8]	0.0 [0.0–6.0]	5.0 [3.0–7.0]	8.0 [5.0–10.0]
		Evening	2.0 [1.2–3.3]	0.0 [0.0–0.0]	5.0 [1.5–8.0]	7.0 [5.0–9.0]
		Night	3.7 [2.0–7.0]	0.0 [0.0–0.0]	0.0 [0.0–7.0]	7.0 [5.0–9.0]
Intensive Care	8	Morning	0.6 [0.5–0.8]	0.0 [0.0–4.0]	2.5 [1.7–3.5]	5.0 [4.0–6.0]
		Evening	0.7 [0.5–1.0]	0.0 [0.0–0.0]	3.5 [2.0–5.0]	5.0 [4.0–6.0]
		Night	1.0 [0.8–1.5]	0.0 [0.0–0.0]	5.0 [0.0–6.0]	6.0 [4.0–6.2]
Neurology, Neurosurgery, Otolaryngology, Head and Neck Surgery, & Ophthalmology	10	Morning	2.2 [1.6–3.0]	5.5 [0.0–10.0]	7.0 [3.7–11.0]	12.0 [9.0–15.0]
		Evening	3.5 [2.2–5.0]	0.0 [0.0–9.0]	5.5 [0.0–11.0]	11.0 [8.0–14.0]
		Night	8.0 [4.5–12.0]	0.0 [0.0–0.0]	0.0 [0.0–11.0]	11.0 [9.0–14.0]
Visceral Surgery and Medicine, Gastroenterology, Thoracic Surgery, & Pulmonology	5	Morning	2.0 [1.6–2.6]	6.3 [1.4–10.5]	8.5 [5.7–13.0]	15.0 [10.0–18.0]
		Evening	3.6 [2.6–5.0]	0.0 [0.0–7.0]	10.5 [6.0–15.0]	14.0 [10.0–17.0]
		night	7.0 [5.0–8.5]	0.0 [0.0–0.0]	0.0 [0.0–14.0]	14.0 [10.0–17.0]
Haematology & oncology	4	morning	2.2 [1.7–3.0]	7.0 [0.0–10.5]	6.3 [3.0–9.0]	10.0 [6.0–17.0]
		Evening	4.7 [2.8–6.0]	2.0 [0.0–9.0]	8.0 [0.0–15.0]	10.0 [6.0–16.0]
		Night	7.0 [3.8–9.0]	0.0 [0.0–0.0]	0.0 [0.0–4.0]	10.0 [6.0–16.0]
Orthopaedics & Plastic Surgery	5	Morning	2.0 [1.6–2.5]	5.0 [0.0–11.0]	9.0 [5.0–12.0]	12.0 [11.0–14.0]
		Evening	4.0 [3.0–5.5]	0.0 [0.0–0.0]	10.0 [6.0–12.0]	11.0 [9.0–13.0]
		Night	11.0 [7.0–13.0]	0.0 [0.0–0.0]	10.0 [0.0–13.0]	12.0 [10.0–13.0]
Dermatology, Urology, Rheumatology, & Nephrology	6	Morning	2.1 [1.6–3.0]	5.0 [2.3–8.0]	6.0 [3.0–11.0]	12.0 [7.0–15.0]
		Evening	3.7 [2.5–5.5]	0.0 [0.0–7.0]	6.0 [0.0–12.0]	11.0 [6.0–14.0]
		Night	7.0 [5.0–12.0]	0.0 [0.0–2.0]	4.0 [0.0–12.0]	11.0 [6.0–15.0]

PRR = patient-to-registered nurse ratio; PLR = patient-to-licensed practical nurse ratio; POR = patient-to-other ratio; *N* = numbers.

with lower odds of mortality −2.7% and −1.5%, respectively. For Others, both high and low were linked to higher mortality odds (+2.6% and +4.4%, respectively). A sensitivity analysis using logistic modeling for the first five days of patients' stays, as well as 36 staffing variables (for shift and weekdays/weekends) provided similar results (see Online supplemental file 4).

4. Discussion

4.1. Main results

For RNs, we found consistent results: shifts with high RN levels were associated with decreased odds of mortality, shifts with low RN levels with increases. Findings for LPNs and Others were not consistent, with effects going in different directions (i.e., both higher and lower staff levels appeared to be associated with both lower and higher odds of mortality). Our results support and add detail to those of previous studies to use longitudinal designs and shift-/daily-, unit-, and patient-level analyses of nurse staffing (Griffiths et al., 2018a; Needleman et al., 2011, 2019). All three reported similar findings regarding the effects of low RN staffing on mortality. The three studies used Cox regression models (hazard of mortality increased by 2%−3%) (Griffiths et al., 2018a; Needleman et al., 2011, 2019). In our study, we found higher odds of mortality (+10%) for lower staffed shifts, but also lower odds of mortality for better staffed shifts (−8.7%). Although our effect sizes cannot be compared directly with the aforementioned studies, the results reflect the same trend: a higher number of RNs is associated with lower rates of mortality.

We found a positive effect of more nurses on mortality in this Swiss hospital. Switzerland is known internationally to offer high quality of care, with relatively high-staffed hospitals compared to most other European countries (Fullman et al., 2018; Sermeus et al., 2011). Our approach used the median number of nurses present over the three years and investigated the deviations from it. This means that if "more" RNs than usual is improving mortality, the hospital has certain shifts where the long-term target (OE=1) seems to be too low.

We focused not only on RNs, but also LPNs and Others as independent variables in order to consider each group's potential contributions to patient mortality (Griffiths et al., 2018a; Needleman et al., 2019). To our knowledge this is the first study considering shifts with not only low, but also high staffing allowing us to explore whether the current staffing levels are appropriate and whether increases in staffing might be linked with lower mortality. Compared to Needleman et al. (2019), we also analyzed one additional nursing staff category, as we did not combine LPNs with Others. This is of high relevance as it provides a perspective on shifting of tasks to less qualified staff groups. As LPNs and other associate degrees are a growing staffing group in healthcare systems worldwide, their effects are of high interest not just in Switzerland (Saudi Patient Safety Center and International Council of Nurses, 2019).

LPNs and Others provided inconsistent results. For example, shifts with high numbers of LPNs were negatively associated with mortality, but also for shifts with low numbers. Similarly, high and low staffing of Others (including unlicensed and administrative personnel) correlated respectively with higher mortality. In the evening, mortality may increase because the least qualified nurse group, unlicensed personnel will less likely detect subtle signs of health deterioration in patients (Brown et al., 2014; Subbe et al., 2017; Vincent et al., 2018). Our findings are in line with previous studies that confirmed RNs' beneficial impact on patient mortality (Buchan et al., 2017; Griffiths et al., 2018). The ongoing lack of conclusive data regarding LPNs' and Others' indicate a need both for further research as independent variables and for caution in their deployment.

Unlike previous researchers, we used an intermediate step to calculate low and high staff variables. Also, instead of nurse hours per patient day (Griffiths et al., 2018a; Needleman et al., 2011, 2019), we used actual numbers of nurses to gage high or low staffing. The O/E ratio is commonly used elsewhere for provider profiling, i.e., comparing quality of care, use of resources among

Table 2
Comparison between patients' demographics variables of alive and mortality cohort.

	Alive cohort (n = 77,663)	Mortality cohort (n = 2230)	Cohen's d
Age (mean (SD))	60.41 (17.63)	70.31 (14.69)	0.61
Gender female (%)	41	41.3	0.01
Stay before admission to hospital (%)			0.37
Home	81.2	65.2	
Home with home care	0.7	2.3	
Other hospital (acute care)	15.4	28.3	
Other	2.7	4.2	
Type of admission (%)			0.93
Emergency	38.9	70.2	
Announced/planned	49.2	11.0	
Transfer	11.1	18.5	
Other	0.8	0.3	
Source of referral (%)			0.62
Own volition/relatives	10.6	6.4	
Rescue service (police, ambulance)	11.9	37.4	
Physician	77.2	56.1	
Other	0.2	0.1	
Stay in ICU, hours (mean (SD))	6.06 (38.35)	52.21 (120.14)	0.52
Stay in ICU = yes (%)	10.9	60.5	1.21
Stay in emergency, hours (mean (SD))	1.73 (3.44)	2.88 (5.97)	0.24
Stay in emergency = yes (%)	40.6	74.3	0.73
LOS (mean (SD))	5.95 (7.42)	8..05 (11.01)	0.22
Number of intra-hospital transfers (mean (SD))	0.70 (1.07)	1.24 (1.70)	0.38
Number of ICD-10-GM diagnoses (mean (SD))	7.73 (6.01)	14.04 (8.98)	0.83
Elixhauser comorbidities by van Walraven (mean (SD))	6.40 (8.11)	15.51 (10.45)	0.97
Cumulative count of shifts with…			
low RN (mean (SD))	0.44 (1.21)	0.69 (2.27)	0.14
high RN (mean (SD))	2.28 (3.01)	2.33 (3.88)	0.02
low LPN (mean (SD))	1.40 (2.26)	1.70 (3.06)	0.11
high LPN (mean (SD))	3.05 (5.88)	3.71 (5.73)	0.11
low Other (mean (SD))	2.08 (3.45)	3.19 (5.64)	0.24
high Other (mean (SD))	2.60 (3.54)	3.89 (5.66)	0.27

Interpretation of Cohen's D: 0.2 = small difference, 0.5 = medium difference, and 0.8 large difference. RN = registered nurse; LPN = licensed practical nurse; Other = unlicensed and administrative personal.

Table 3
Staffing variables in the mortality model split by nurse group with odds ratios and 95% confidence intervals, p-values, and percentages.

		Coefficients [95% CI]	P value	Difference in odds of death
Cumulative count of shifts with low/high numbers of staff				
RN	Low	1.10 [1.07–1.13]	$<$ 0.001	+10%
	High	0.91 [0.89–0.93]	$<$ 0.001	−8.7%
LPN	Low	0.99 [0.96–1.01]	0.235	−1.5%
	High	0.97 [0.96–0.99]	$<$ 0.001	−2.7%
Other	Low	1.04 [1.03–1.06]	$<$ 0.001	+4.4%
	High	1.03 [1.01–1.04]	0.004	+2.6%

medical providers and to reflect overall performance (Galvan-Turner et al., 2015; Ibáñez et al., 2009). It is also a simple statistical method for standardization (MacKenzie et al., 2015; Manda et al., 2012). In our case, we needed to standardize the expected number of nurses (RNs, LPNs, and Others) based on unit characteristics. As the number of nurses is often unit-specific, our model included separate calculations for each unit's ratio (hence the absence of a multilevel approach). The O/E ratio describes what is the usual expected nurse staffing level given the unit's characteristics. We used the deviation from the expected number of nurses in order to see the impact of more and less nurses than the median. Finally, an explicit O/E staffing model is also flexible in integrating additional workload indicators, while providing results comparable to those reported elsewhere in this field.

Concerns have been raised that the association of mortality to nursing care may be overstated, since the hospital environment is a multidisciplinary collaboration and thus mortality is the result of several elements not only due to nursing care. Such effects might be relatively small in the given design since staffing variability in this study is over-time rather than between sites.

4.2. Limitations

While our study has several noteworthy strengths, including its longitudinal design and shift-, unit-, and patient-level analysis, it also has some limitations. One was the choice of cut-off thresholds of double and half of the median O/E. As no consensus exists regarding how optimal staffing levels are defined (Saville et al., 2019), we chose these based on our experience conducting an earlier descriptive study (Musy et al., 2020). Numerous cut-off thresholds have been used elsewhere, including the mean, target level and 75% below the median (Fagerström et al., 2018; Griffiths et al., 2018; Needleman et al., 2011, 2019). This variation indicates a need for a standard method of determining a level appropriate to achieve optimal patient outcomes (Needleman and Shekelle, 2019). As noted above, we have no evidence that our chosen thresholds were optimal. And it is possible that a different cut-off threshold should be used for each nurse group, unit, or shift. Furthermore, the median value of O/E, depends on the observed number of nurses. If a unit is continually under- or overstaffed, the O/E median and cutoff thresholds would be skewed accordingly. However, this problem assumes an empirical process of deriving those thresholds.

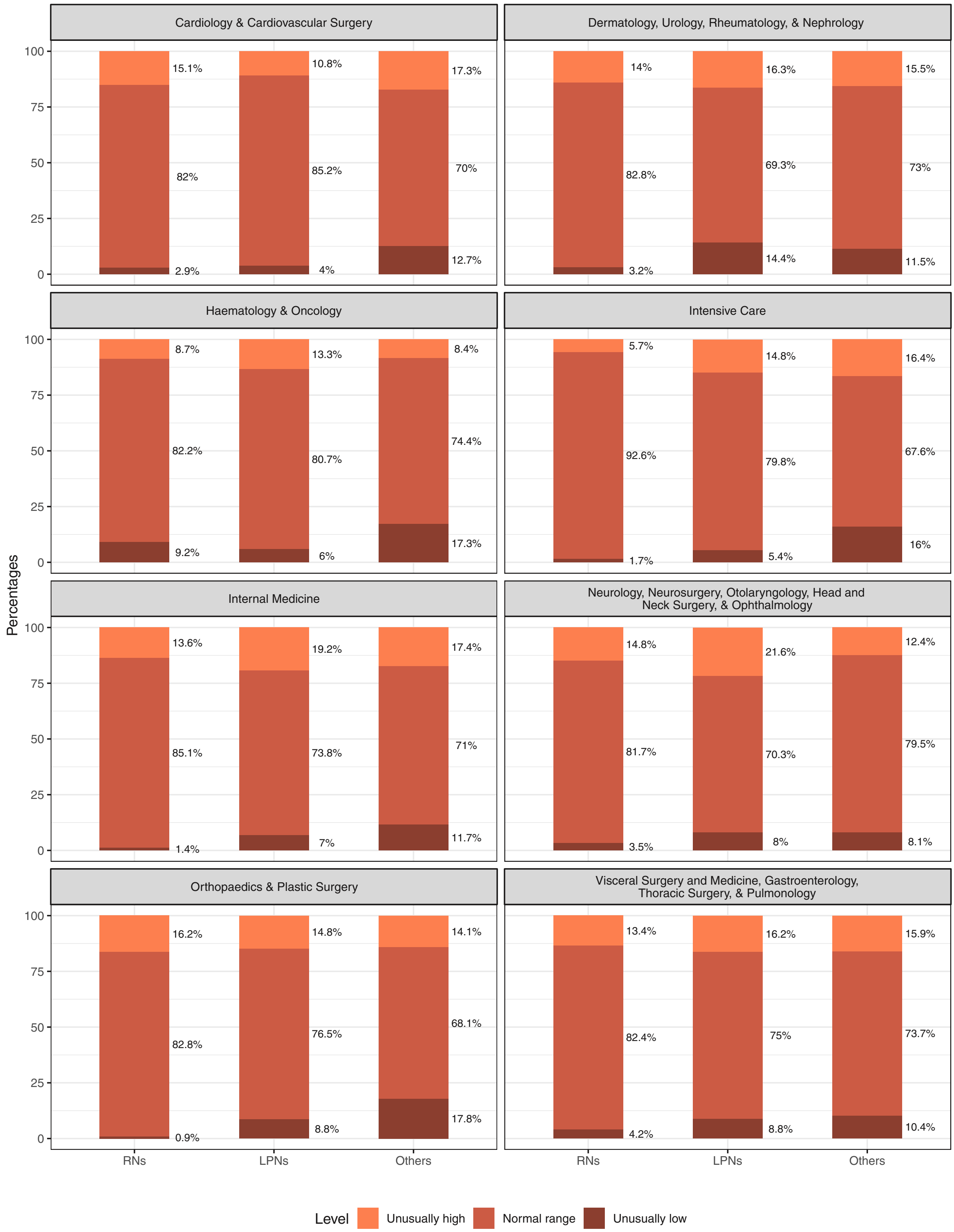

Fig. 2. Percentages of shifts with unusually low and high staffing for each department and each nurse group (RNs, LPNs, and Others).

Regarding the groups of nurses, two points should be highlighted. First, as the Others group represented a combination of unlicensed and administrative personnel, we could not attribute which group has which effect. Splitting the Others variable would have offered added value, but was not possible given our sample's scarcity of data in this staff group. Second, as the sample unit staffs generally included few external nurses or students (three-year daily median: 0), and as (for administrative reasons) our datasets included no working time data for them, these groups were excluded even from our descriptive analysis.

Another limitation was that we did not use interaction terms. Due to the number of staffing variables, meaningful incorporation of interactions was challenging. Nevertheless, future studies should explore interactions. Needleman et al. (2019) – treating low RN staffing and low nursing support as a single variable – might be worthwhile to explore (Needleman et al., 2019).

Finally, the study was undertaken in a single hospital, further investigations will thus be needed.

5. Conclusion

This high-granularity longitudinal study indicates a possible relationship between high RN staffing levels and improved patient mortality (Driscoll et al., 2018; Fagerström et al., 2018; Griffiths et al., 2018; Kane et al., 2007; Needleman et al., 2011, 2019). It also eliminates alternative explanations for the association between nurse staffing and mortality, making a causal link more likely (Shekelle, 2013). Including this study, four longitudinal studies using shift-/daily, unit-, and patient-level analysis have consistently linked low RN staffing levels with increases in mortality. Nevertheless, uncertainty remains concerning the outcomes most directly linked to the quality of nursing care (e.g. pressure ulcers). Understanding such outcomes is imperative to accurately quantify nurses' contribution to patient care. To our knowledge, the current study is the first to examine the association of nurse staffing with mortality in Switzerland. Knowing the high quality of Swiss hospital environments, the findings suggest that even in the Swiss system, patients both benefit from high RN-staffed shifts and suffer (i.e., higher risk of death) from low RN staffing. As noted above, while results for LPNs and Others need further research, one clear implication is that substituting them for RNs is not advisable. Finally, research about what constitutes appropriate nurse staffing is urgently needed.

Conflict of Interest

None.

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Supplementary materials

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References

Aiken, L.H., Sloane, D.M., Bruyneel, L., Van den Heede, K., Sermeus, W., Consortium, R.C., 2013. Nurses' reports of working conditions and hospital quality of care in 12 countries in Europe. Int. J. Nurs. Stud. 50 (2), 143–153. doi:10.1016/j.ijnurstu.2012.11.009.

Austin, P.C., 2011. An introduction to propensity score methods for reducing the effects of confounding in observational studies. Multivar. Behav. Res. 46 (3), 399–424. doi:10.1080/00273171.2011.568786.

Blay, N., Roche, M.A., Duffield, C., Gallagher, R., 2017. Intrahospital transfers and the impact on nursing workload. J. Clin. Nurs. 26 (23–24), 4822–4829. doi:10.1111/jocn.13838.

Brown, H., Terrence, J., Vasquez, P., Bates, D.W., Zimlichman, E., 2014. Continuous monitoring in an inpatient medical-surgical unit: a controlled clinical trial. Am. J. Med. 127 (3), 226–232.

Buchan, J., Seccombe, I., Gershlick, B., Charlesworth, A., 2017. In Short Supply: Pay Policy and Nurse Numbers. The Health Foundation.

Driscoll, A., Grant, M.J., Carroll, D., Dalton, S., Deaton, C., Jones, I., ..., Astin, F., 2018. The effect of nurse-to-patient ratios on nurse-sensitive patient outcomes in acute specialist units: a systematic review and meta-analysis. Eur. J. Cardiovasc. Nurs. 17 (1), 6–22. doi:10.1177/1474515117721561.

Elixhauser, A., Steiner, C., Harris, D.R., Coffey, R.M., 1998. Comorbidity measures for use with administrative data. Med. Care 8–27. doi:10.1097/00005650-199801000-00004.

Fagerström, L., Kinnunen, M., Saarela, J., 2018. Nursing workload, patient safety incidents and mortality: an observational study from Finland. BMJ Open 8 (4), e016367. doi:10.1136/bmjopen-2017-016367.

Fullman, N., Yearwood, J., Abay, S.M., Abbafati, C., Abd-Allah, F., Abdela, J., ..., Aboyans, V., 2018. Measuring performance on the healthcare access and quality index for 195 countries and territories and selected subnational locations: a systematic analysis from the global burden of disease study 2016. Lancet N. Am. Ed. 391 (10136), 2236–2271.

Galvan-Turner, V.B., Chang, J., Ziogas, A., Bristow, R.E., 2015. Observed-to-expected ratio for adherence to treatment guidelines as a quality of care indicator for ovarian cancer. Gynecol. Oncol. 139 (3), 495–499. doi:10.1016/j.ygyno.2015.09.015.

Griffiths, P., Ball, J., Drennan, J., Dall'Ora, C., Jones, J., Maruotti, A., ..., Simon, M., 2016. Nurse staffing and patient outcomes: strengths and limitations of the evidence to inform policy and practice. A review and discussion paper based on evidence reviewed for the National Institute for Health and Care Excellence Safe Staffing guideline development. Int. J. Nurs. Stud. 63, 213–225. doi:10.1016/j.ijnurstu.2016.03.012.

Griffiths, P., Maruotti, A., Saucedo, A.R., Redfern, O.C., Ball, J.E., Briggs, J., ..., Smith, G.B., 2018a. Nurse staffing, nursing assistants and hospital mortality: retrospective longitudinal cohort study. BMJ Qual. Saf. 28 (8), 609–617. doi:10.1136/bmjqs-2018-008043.

Griffiths, P., Recio-Saucedo, A., Dall'Ora, C., Briggs, J., Maruotti, A., Meredith, P., ...Missed Care Study Group, 2018b. The association between nurse staffing and omissions in nursing care: a systematic review. J. Adv. Nurs. 74 (7), 1474–1487. doi:10.1111/jan.13564.

Ibáñez, B., Librero, J., Bernal-Delgado, E., Peiró, S., López-Valcarcel, B.G., Martínez, N., Aizpuru, F., 2009. Is there much variation in variation? Revisiting statistics of small area variation in health services research. BMC Health Serv. Res. 9 (1), 60. doi:10.1186/1472-6963-9-60.

Jennings, B.M., Sandelowski, M., Higgins, M.K., 2013. Turning over patient turnover: an ethnographic study of admissions, discharges, and transfers. Res. Nurs. Health 36 (6), 554–566. doi:10.1002/nur.21565.

Kane, R.L., Shamliyan, T.A., Mueller, C., Duval, S., Wilt, T.J., 2007. The association of registered nurse staffing levels and patient outcomes: systematic review and meta-analysis. Med. Care 45 (12), 1195–1204. doi:10.1097/MLR.0b013e3181468ca3.

MacKenzie, T.A., Grunkemeier, G.L., Grunwald, G.K., O'Malley, A.J., Bohn, C., Wu, Y., Malenka, D.J, 2015. A primer on using shrinkage to compare in-hospital mortality between centers. Ann. Thorac. Surg. 99 (3), 757–761. doi:10.1016/j.athoracsur.2014.11.039.

Manda, S.O., Gale, C.P., Hall, A.S., & Gilthorpe, M.S.. (2012). Statistical profiling of hospital performance using acute coronary syndrome mortality. 23(10), 546. doi:10.5830/CVJA-2011-064

Menendez, M.E., Neuhaus, V., van Dijk, C.N., Ring, D., 2014. The Elixhauser comorbidity method outperforms the Charlson index in predicting inpatient death after orthopaedic surgery. Clin. Orthop. Relat. Res.® 472 (9), 2878–2886. doi:10.1007/s11999-014-3686-7.

Musy, S.N., Endrich, O., Leichtle, A.B., Griffiths, P., Nakas, C.T., Simon, M., 2020. A longitudinal study on the variation of patient turnover and patient-to-nurse ratio: descriptive analysis of a Swiss University Hospital. J Med. Int. Res. 22 (4), e15554.

Needleman, J., Buerhaus, P., Pankratz, V.S., Leibson, C.L., Stevens, S.R., Harris, M., 2011. Nurse staffing and inpatient hospital mortality. N. Engl. J. Med. 364 (11), 1037–1045. doi:10.1056/NEJMsa1001025.

Needleman, J., Liu, J., Shang, J., Larson, E.L., Stone, P.W., 2019. Association of registered nurse and nursing support staffing with inpatient hospital mortality. BMJ Qual. Saf. bmjqs-2018-009219.

Needleman, J., Shekelle, P.G., 2019. More ward nursing staff improves inpatient outcomes, but how much is enough? BMJ Qual. Saf. doi:10.1136/bmjqs-2018-009266.

R. Core Team. (2017). R: a language and environment for statistical computing. Retrieved from https://www.R-project.org/

Saudi Patient Safety Center; International Council of Nurses. (2019). Nurse staffing levels for patient safety and workforce safety. *SPSC and ICN White Paper*.

Saville, C.E., Griffiths, P., Ball, J.E., Monks, T., 2019. How many nurses do we need? A review and discussion of operational research techniques applied to nurse staffing. Int. J. Nurs. Stud. doi:10.1016/j.ijnurstu.2019.04.015.

Sermeus, W., Aiken, L.H., Van den Heede, K., Rafferty, A.M., Griffiths, P., Moreno-Casbas, M.T., ..., Zikos, D., 2011. Nurse forecasting in Europe (RN4CAST): rationale, design and methodology. BMC Nurs. 10, 6. doi:10.1186/1472-6955-10-6.

Shekelle, P.G., 2013. Nurse–patient ratios as a patient safety strategy. A systematic review. Ann. Intern. Med. 158 (5_Part_2), 404–409. doi:10.7326/0003-4819-158-5-201303051-00007.

Subbe, C.P., Duller, B., Bellomo, R., 2017. Effect of an automated notification system for deteriorating ward patients on clinical outcomes. Crit. Care 21 (1), 52. doi:10.1186/s13054-017-1635-z.

Thompson, N.R., Fan, Y., Dalton, J.E., Jehi, L., Rosenbaum, B.P., Vadera, S., Griffith, S.D., 2015. A new Elixhauser-based comorbidity summary measure to predict in-hospital mortality. Med. Care 53 (4), 374. doi:10.1097/mlr.0000000000000326.

Twigg, D., Duffield, C., Bremner, A., Rapley, P., Finn, J., 2011. The impact of the nursing hours per patient day (NHPPD) staffing method on patient outcomes: a retrospective analysis of patient and staffing data. Int. J. Nurs. Stud. 48 (5), 540–548. doi:10.1016/j.ijnurstu.2010.07.013.

Van den Heede, K., Clarke, S.P., Sermeus, W., Vleugels, A., Aiken, L.H., 2007. International experts' perspectives on the state of the nurse staffing and patient outcomes literature. J. Nurs. Scholarsh. 39 (4), 290–297. doi:10.1111/j.1547-5069.2007.00183.x.

van Walraven, C., Austin, P.C., Jennings, A., Quan, H., Forster, A.J., 2009. A modification of the Elixhauser comorbidity measures into a point system for hospital death using administrative data. Med. Care 626–633. doi:10.1097/mlr.0b013e31819432e5.

Vincent, J.-L., Einav, S., Pearse, R., Jaber, S., Kranke, P., Overdyk, F.J., ..., Hoeft, A., 2018. Improving detection of patient deterioration in the general hospital ward environment. Eur. J. Anaesthesiol. 35 (5), 325. doi:10.1097/EJA.0000000000000798.