Nurses' reports of staffing adequacy and surgical site infections: A cross-sectional multi-centre study

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ABSTRACT

Background: It is indicated that healthcare personnel's perceptions of the work environment may reflect the clinical outcomes for the patients they care for. However, the body of evidence is inconsistent when it comes to the association between work environment and surgical site infection.
Objectives: The aim of this study is to examine the associations between nurse-reported characteristics of the work environment and incidence of surgical site infections after total hip arthroplasty.
Design and settings: This is a cross-sectional multicentre study conducted in 16 Norwegian hospitals.
Participants: Clinical outcomes for 2885 patients > 18 years that underwent total hip arthroplasty are combined with work environment descriptions from 320 nurses.
Materials and methods: We combine data about surgical site infections from The Norwegian Surveillance System for Antibiotic Consumption and Healthcare-Associated Infections and hospital characteristics such as overall survival probability (from administrative patient data) and nurses' reports of characteristics of the work environment (from a multicentre survey among nurses in Norwegian hospitals). Stepwise mixed-effects logistic regression model was performed to examine the associations between characteristics of the work environment and surgical site infections.
Results: The incidence of surgical site infection among 2885 patients undergoing total hip arthroplasty in 16 Norwegian hospitals was 2.6%. Older age, elective procedures and high scores for staffing adequacy were associated with risk for surgical site infection. The association between high scores for adequate staffing and low risk for surgical site infections was present for patients that were admitted for an elective procedure, but not for patients admitted for a non-elective procedure.
Conclusion: Our results show that the risk of surgical site infections after elective total hip arthroplasty was lower in hospitals where nurses assessed staffing as adequate. Our findings add to the existing literature that examines the linkage between work environment and clinical outcomes.

What is already known about the topic?

- Healthcare associated infections are associated with understaffing, high bed occupancy and workload.
- The body of evidence is inconsistent when it comes to the association between work environment and surgical site infection.

What this paper adds

- Nurses' perceptions of staffing adequacy are associated with risk for surgical site infection after planned total hip arthroplasty.

- The interaction between staffing adequacy and procedure type emphasizes the complexity of healthcare organisation and evaluation of clinical outcomes.

1. Background

Surgical site infections are among the most common complications after orthopaedic surgery (Ohrn et al., 2012), and it is suggested that 55% of surgical site infections are preventable (Umscheid et al., 2011). In a systematic review the authors concluded that surgical site infections could be reduced to less than 1% after procedures classified as

clean (Alexander et al., 2011). Total hip arthroplasty is a clean surgical procedure, yet, the incidence of surgical site infections after this procedure is normally higher than 1%, and this kind of complication exposes patients to serious consequences such as pain, disablement, and mortality (Gagliardi et al., 2009). Moreover, prolonged hospitalisation and readmissions due to surgical site infections lead to increased costs for the health care system (Alexander et al., 2011; Lasater and McHugh, 2016). Efforts to reduce the incidence of these infections have traditionally been targeted towards improvement of clinical processes related to the surgical procedure such as preoperative body hair removal by use of clippers (Kapadia et al., 2013) and patient preparation such as smoking cessation (Duchman et al., 2015; Gagliardi et al., 2009; Nessim et al., 2012). The inconsistent results of such interventions have been explained by lack of adherence to recommended guidelines. However, it is questioned whether a high adherence to guidelines is sufficient to reduce the incidence of surgical site infections (Gagliardi et al., 2009; Hawn et al., 2011). A qualitative study evaluating prevention practices for surgical site infections emphasized that organisational strategies such as enhancement of multidisciplinary teamwork are necessary to reduce infections (Nessim et al., 2012), and in a recent review, the authors address the hospital management and organisational features to identify crucial elements for prevention of healthcare associated infections (Zingg et al., 2015). The acknowledgement of an organisational approach towards quality and safety issues in healthcare has made the system perspective more influential during the last two decades. In research prompted by the recognition that errors occur in complex systems, it has been suggested that organisational transformation may be necessary to make sustainable quality improvements possible (Braithwaite et al., 2015; Leape et al., 2009).

According to James Reason's theory of human error, a complex organisation possesses different defensive layers to prevent the occurrence of errors (Reason, 2000). Some of these layers are related to the physical environment, for example by having a safe and appropriate laminar air flow system in the operation theatre. Other layers rely on people, for example by the skills of members of the operating team to avoid contamination of the sterile field. Procedures and administrative controls are layers that protect against process failures, for example double checking administration of antibiotic prophylaxis. However, the defensive layers may have lapses that compromise the protection against accidents. The double check of antibiotic prophylaxis may for example be missed if the ward personnel is uninformed about when the patient is scheduled for surgery. Latent conditions of the layers may protect against or provoke errors through conditions within the local workplace (for example by prolonged preoperative waiting time, understaffing and problems with communication) (Reason, 2000). In an adaption of Reason's model for use in healthcare, error producing conditions are classified in seven levels of safety: patient factors, task and technology factors, individual staff factors, team factors, working conditions, organisational environment and the wider institutional context (Vincent, 2003).

Research showing that healthcare personnel's perceptions of their work environment are associated with clinical outcomes, supports this framework. Nurses constitute a large proportion of healthcare personnel, and hold key roles in the healthcare delivery. They spend more time close to the patients than other healthcare professionals and collaborate with all providers of care in the hospital. Their assessments of the work environment are therefore considered important indicators for organisational characteristics that have been associated with quality of care (Stalpers et al., 2015). Nurses' evaluations of teamwork, work pressure and leadership are associated with patient outcomes such as mortality, failure to rescue, length of stay and health status after discharge (Aiken et al., 2008; Bae, 2011; Kee et al., 2005; Shang et al., 2012; Smeds-Alenius et al., 2016; Stone et al., 2007). Moreover, associations between nurses' work environment and clinical outcomes such as mortality and readmissions has been addressed by several researchers (Cho et al., 2016; Ma et al., 2015; McHugh and Ma, 2013;

McHugh et al., 2016; Stalpers et al., 2015; Tvedt et al., 2014). However, we were not able to find studies that described the relationship between work environment and healthcare associated infections, even though healthcare associated infections are associated with nurse staffing, high occupancy and high workload (Hugonnet et al., 2004; Stone et al., 2008; Zingg et al., 2015). In previous research, we showed that hospital mortality was associated with nurses' assessment of staffing adequacy, but not with the nurse-patient ratio (Tvedt et al., 2014). We therefore assume that nurses' assessments of the work environment represent characteristics of the organization that is relevant for performance and quality of care of the hospitals. To our knowledge, the relationship between work environment and surgical site infections has not previously been studied. The objective of the present study is to examine the associations between work environment and surgical site infections after total hip arthroplasty. Total hip replacement is a clean procedure, and it is anticipated that the infection rates are low. However, the incidence of surgical site infections varies between hospitals, and organisational characteristics such as nurses' work environment may be indictors for hospital performance and consequently the infections rates.

2. Objectives

The aim of this study is to examine the associations between nurse-reported characteristics of the work environment and incidence of surgical site infections after total hip arthroplasty.

3. Methods

3.1. Design

In this cross-sectional multicentre study, we combined variables from three sources:

1) Descriptions of nurse-reported characteristics of the work environment from a cross-sectional survey (2009).

- Staffing adequacy
- Nurse-physician relationship
- Quality system
- Patient safety management
- Quality of nursing

2) Probabilities of being alive within 30 days after hospital admission reported for patients discharged from Norwegian hospitals, i.e. for diagnoses included in the group of diagnoses causing 80% of hospital deaths (2005–2009).

- Overall survival

3) Data from The Norwegian Surveillance System for Antibiotic Consumption and Healthcare-Associated Infections (NOIS) to determine the incidence of surgical site infections after total hip arthroplasty (2005–2009).

- Age
- Gender
- Procedure type (elective/non-elective)
- Surgical site infection status after total hip arthroplasty (dependent variable)

3.2. Settings

The present study included patients from 16 Norwegian hospitals with 20 wards specialized in orthopaedic care. The included hospitals make up 46% of the 35 Norwegian hospitals that had more than 90 beds in 2009.

Table 1

Subscales from the nurse survey that describe characteristics of the work environment (independent variables). The internal consistency for the Norwegian dataset is also reported in previous work (Tvedt et al., 2012).

Subscale	Internal consistency (Cronbach's alpha)	Instrument	Response format	Single items for each subscale
Staffing adequacy	0.80	PES-NWI	Four-point Likert-type scale[a]	Enough time and opportunity to discuss patient care problems with other nurses
				Enough registered nurses to provide quality patient care
				Enough staff to get the work done
Nurse-physician relationship	0.88	PES-NWI	Four-point Likert-type scale[a]	Physicians and nurses have good working relationships
				A lot of team work between nurses and physicians
				Collaboration (joint practice) between nurses and physicians
				Physicians value nurses' observations and judgments
				Physicians recognize nurses' contributions to patient care
				Physicians respect nurses as professionals
				Physicians hold nurses in high esteem
Quality system	0.71	PES-NWI	Four-point Likert-type scale[a]	A clear philosophy of nursing that pervades the patient care environment
				Working with nurses who are clinically competent
				An active quality assurance program
				A preceptor program for newly hired registered nurses
				Nursing care is based on a nursing, rather than a medical, model
				Written, up-to-date nursing care plans for all patients
				Patient care assignments that foster continuity of care (i.e. the same nurse cares for the patient from one day to the next)
Patient safety management	0.72	HSOPSC	Five-point Likert-type scale[b]	In this unit we discuss ways to prevent errors from happening again
				We are given feedback about changes put into place based on event reports
				The actions of hospital management show that patient safety is a top priority

[a] 1 = strongly disagree, 2 = somewhat disagree, 3 = somewhat agree, and 4 = strongly agree.
[b] 1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, and 5 = strongly agree.

3.3. Data collection

The overall survival rates per hospital (Hassani et al., 2015) and nurse-reported characteristics of the work environment were used as descriptions of the organisations.

3.4. Nurse-reported organisational characteristics

A self-administered, printed questionnaire was distributed to nurses working in Norwegian hospitals with more than 85 beds in 2009 as part of the international RN4Cast study (Sermeus et al., 2011). The questionnaire was translated into Norwegian using standardized methods, and found acceptable for use in a Norwegian context (Tvedt et al., 2012). The data collection method is described in detail in previous work where five subscales were found to be associated with nurse-reported quality and safety (Table 1) (Tvedt et al., 2012). Data from the Practice Environment Scale of the Nursing Work Index (PES-NWI) (Lake, 2002) and the Hospital Survey on Patient Safety Culture (HSOPSC) were used as descriptions of the work environment (Blegen et al., 2009).

The subscales are considered measures that operationalize characteristics of the work system. Moreover, a single item from the questionnaire was included as a description of nurse-assessed quality: "In general, how would you describe the quality of nursing care delivered to patients on your unit/ward?" (Four-point Likert-type scale where 1 = poor, 2 = fair, 3 = good, 4 = excellent). The numerical scores were used in the analysis.

3.5. Hospital quality indicator: overall survival

The Norwegian Knowledge Centre for the Health Services, later incorporated in the Norwegian Institute of Public Health (NIPH) has estimated probabilities for patients being alive within 30 days after admission in or out of hospital, based on administrative data for patients discharged from Norwegian hospitals (Helgeland et al., 2011). Overall survival probabilities (hereafter referred to as "overall survival") based on diagnosis groups that account for 80% of all hospital deaths, were estimated for hospitals with more than 800 admissions for 2009. The procedure is an adaptation of estimation of hospital standardized mortality rates (HSMR) (Jarman et al., 2010). Risk adjustments were made for age, sex, number of admissions (during the previous 2 years) and Charlson comorbidity index (Hassani et al., 2015; Kristoffersen et al., 2012). Overall survival is reported by NIPH as a quality indicator for Norwegian hospitals. In the present study we used this indicator to control for variations between the hospitals' performance (Hassani et al., 2015).

3.6. Clinical outcomes: surgical site infections

The NOIS (Norwegian Surveillance System for Antibiotic Consumption and Healthcare-Associated Infections) is managed by NIPH, and hospital participation in the surveillance system has been mandatory since 2005 (NOIS, 2013). The NOIS protocol is based on the protocol for surveillance of surgical site infections in European hospitals from the European Centre for Disease Prevention and Control (ECDC, 2012). De-identified data about the surgical procedure, procedure type (elective/non-elective), infection status, risk factors, mortality, admission and discharge dates during a 3-month period (September–November) have been provided annually from the hospitals to the NIPH. We included total hip arthroplasty in the present study since it is a clean procedure and since most of the Norwegian hospitals provided data for this procedure. The present study includes hospitals which submitted data from at least 50 patients to NOIS during the study period (2005–2009). We included all patients > 18 years that underwent total hip arthroplasty that were followed up for 30 days after surgery during 2005–2009 (NOIS, 2013). The full scope of the surveillance system is thoroughly described elsewhere (Lower et al., 2013). The clinical outcome measure in the present study was physician-

Table 2
Distribution of age groups among patients included in the study, overall and for patient undergoing elective procedures.

Age groups	Frequency: age groups	Percent: age groups	Frequency: elective procedures:	Percent: elective procedures
< 29	7	0.2	6	0.3
30–39	21	0.7	18	0.9
40–49	81	2.8	69	3.6
50–59	240	8.3	199	10.3
60–69	652	22.6	553	28.7
70–79	875	30.3	642	33.3
80–89	848	29.4	406	21.1
> 90	157	5.4	35	1.8
Missing	4			
Total	2885	100.0	1928	100

confirmed deep or organ/space surgical site infection following the standardized criteria of the Centers for Disease Control and Prevention/National Nosocomial Infections Surveillance (Horan et al., 1992).

Adjustments were made for risk factors such as gender, age groups (ten years' groups) and procedure type (elective versus non-elective procedures). Elective procedures are defined by the data collector at each hospital as procedures that are planned more than 24 h in advance. For patients with osteoarthritis, total hip arthroplasty is most commonly performed as an elective procedure. For patients with hip fracture, hemiarthroplasty is most commonly performed as a non-elective procedure. Each patient in the NOIS-data was assigned averaged scores for the nurse-reported subscales per hospital (i.e. staffing adequacy, nurse-physician relationship, quality system and patient safety management) and the overall survival probability estimated for the hospitals in which they were cared for.

3.7. Ethical approvals

The Data Protection Official for Research approved the method for data collection and handling of the nurse survey. Data from NOIS were provided by NIPH after approval by the Regional Committees for Medical and Health Research Ethics and notification to the Data Protection Official for Research. Overall survival was published as national quality indicator thus ethical approval was not necessary for this part of the data material (Helgeland et al., 2011).

3.8. Statistical analysis

Analyses were conducted to describe the patient population according to the age distribution, gender, procedure type and incidence of surgical site infections among patients undergoing total hip arthroplasty. The age groups variable was numbered from 1 to 8, where group 1 represent age below 29 years. Group 2–7 are ten years groups (30–39, 40–49, 50–59, 60–69, 70–79, 80–89), and group 8 are individuals more than 90 years old. The nurse-reported subscales and the scores from the quality of nursing item were transformed linearly to 0–100 scales, with the lowest possible value of corresponding to 0 and the highest possible value corresponding to 100. Thus, higher scores represent more positive descriptions. The scale scores from the nurse survey are described by means and standard deviations. The probabilities of overall survival are described by mean, standard deviation and minimum–maximum values. To adjust for the possibility of hospital factors outside the model introducing dependencies between patients, mixed-effects logistic regression model was used, introducing hospitals as a level 2 variable. Univariate mixed effects logistic regression was performed to examine the associations between the independent variables (nurse-reported subscales, nurse-assessed quality of care, overall survival) and the clinical outcome: surgical site infection after total hip arthroplasty. Independent variables that were significantly associated

with the clinical outcome variable in univariate analyses were included in the multivariate mixed effects logistic regression model, and results are presented by odds ratios, 95% confidence intervals and p-values. Stepwise multivariate mixed effects logistic regression was used, including two-variable interactions, as we could not a priori rule out such interactions. Independent variables that were significantly associated with the outcome variable were included in the model and were constrained to remain in the model. Only complete cases were used in the final multivariate model. Results are presented by odds ratios, 95% confidence intervals and p-values. The intraclass correlation coefficients for multivariate mixed effects logistic regression are reported. IBM SPSS Statistics for Macintosh, Version 22.0 (IBM Corp., Armonk, N.Y., USA) was used for descriptive statistics and STATA 13.1 (StataCorp, Texas, USA) for mixed-effects logistic regression.

4. Results

Surgical site infection within 30 days was diagnosed in 74 of the 2885 patients (2.6%). The incidence percentage of surgical site infections was 1.7% after elective procedures and 4.9% after non-elective procedures. Elective procedures were most frequent (70.8%), and most of the patients were over 60 years old (Table 2). A majority of the patients were female (69.3%), and the patients were admitted to 16 Norwegian hospitals. The number of patients per hospital ranged from 59 to 137 during the period.

The response rates in the nurse survey were above 40% in all 16 hospitals and employed 511 nurses, of whom 320 returned the questionnaire (overall response rate: 62.6%). The mean scores (and standard deviations) of subscales and single items among these respondents are presented in Table 3. The poorest score was found for the scale staffing adequacy with a mean score of 47.5 The mean score of nurses' assessments of the quality of nursing was 68.9 (Table 3).

The overall survival probabilities per hospital ranged between 92.5–96.2 and the mean overall survival probability was 94.9 (standard deviation 0.8).

In univariate mixed effects logistic regression models higher age groups, non-elective procedure and low scores for nurse-reported staffing adequacy were associated with risk for surgical site infection (Table 4). Whereas overall survival, nurses' reports on the quality system, patient safety management, nurse-physician relationship and quality of nursing were not. We therefore excluded the statistically non-significant variables from further analysis.

The interaction between nurses' reports on staffing adequacy and procedure type (elective/non-elective) was significant, and the interaction was therefore included in the stepwise mixed effects logistic regression. The results of the stepwise mixed effects logistic regression that is described in Table 5 show that age, elective procedure and the interaction between staffing adequacy and procedure type are significantly associated with surgical site infection. The intraclass correlation coefficient was 0.03 for the model in Table 5.

In the resulting model, staffing adequacy is not significant for non-elective procedures, while the risk for surgical site infections for elective procedures is significantly lower if staffing is perceived as adequate. The association between surgical site infections and the interaction with staffing adequacy and procedure type is illustrated in Fig. 1.

Table 3
Nurse-reported work environment and quality of nursing: mean scores and standard deviations at the nurse level (scale scores from 0 to 100).

	Mean scores	Standard deviation
Staffing adequacy	47.5	23.4
Nurse-physician relationship	64.6	16.9
Quality system	55.5	16.3
Patient safety management	56.4	18.1
Quality of nursing	68.9	19.2

Table 4

Univariate mixed-effects logistic regression model for the associations between independent variables and surgical site infections (patients: level 1* and hospitals: level 2**).

Variables	Surgical site infection after total hip arthroplasty		
	Odds ratio	95% confidence interval	p-value
Elective procedure* (reference: non-elective)	0.40	0.24, 0.67	p < 0.001
Age group*	1.04	1.02, 1.07	p < 0.001
Staffing adequacy**	0.97	0.95, 0.99	p = 0.009
Overall survival**	0.81	0.46, 1.43	p = 0.476
Nurses' reports on the quality system**	0.99	0.95, 1.05	p = 0.938
Patient safety management**	1.00	0.96, 1.04	p = 0.980
Nurse-physician relationship**	0.99	0.95, 1.05	p = 0.935
Quality of nursing**	1.00	0.96, 1.04	p = 0.984

Table 5

Mixed-effects logistic regression model for the associations between independent variables and surgical site infections including the interaction between staffing adequacy and procedure type (n = 2724) (patients: level 1* and hospital: level 2**).

Variables	Surgical site infection after total hip arthroplasty		
	Odds ratio	95% confidence interval	p-value
Staffing adequacy	1.00	0.96, 1.02	0.670
Age group	1.03	1.01, 1.06	0.008
Non-elective procedure	1	–	–
Elective procedure	5.4	1.34, 21.7	0.017
Interaction: elective procedure × staffing adequacy	0.94	0.91, 0.97	0.001
	Log-odds	95% confidence interval	p-value
Hospital	0.11[a]	0.01, 0.96	

[a] Variance.

5. Discussion

In the present study, we found that the risk of surgical site infections after total hip arthroplasty was lower in hospitals where nurses reported high scores for staffing adequacy compared to hospitals where nurses reported low scores for staffing adequacy. The effect of staffing adequacy on surgical site infections depends on whether the patients were admitted for an elective procedure or not.

Our finding showing a relationship between nurses' scores for staffing adequacy and surgical site infections for patients undergoing total hip arthroplasty is supported by findings from a study involving patients that underwent joint replacement (including total hip arthroplasty). This study showed that fewer patients are readmitted within 30 days in hospitals with a positive work environment (Lasater and McHugh, 2016). The last decades the evidence for associations between nurses' work environment and clinical outcomes such as mortality and readmissions has been strengthened by several studies (Cho et al., 2016; Ma et al., 2015; McHugh and Ma, 2013; McHugh et al., 2016; Stalpers et al., 2015; Tvedt et al., 2014). These studies support the accepted models where patient outcomes are described as results of a multifactorial interplay between the patient, tasks and technology, staff, team, work environment, organisational and institutional environment (Emanuel et al., 2008; Reason, 2000; Vincent, 2003; Vincent and Amalberti, 2016). Nurses are working bedside around the clock, and their proximity to the patients and close collaboration with all healthcare professionals provide them with first-hand information about such factors and the interplay between them. They are therefore considered a reliable source for organisational characteristics.

In the present study, we examined nurses' scores for staffing adequacy as one of several indicators for the organisational qualities based on the assumption that the premises for high clinical performance lie in the organisational environment (Emanuel et al., 2008; Reason, 2000; Vincent, 2003; Vincent and Amalberti, 2016). The subscale "staffing adequacy" is associated with factors such as indicators for patient mix and personnel mix, accessibility of assistive personnel, cohesiveness of staff and nurse-patient continuity (Kalisch et al., 2011; Kramer and Schmalenberg, 2005; Mark et al., 2002). Our data did not enable us to examine the correlations between staffing levels and nurses' scores for staffing adequacy, and it has been emphasized that perceived staffing adequacies do not reflect the actual nurse-to-patient ratio (Kalisch et al., 2011; Mark et al., 2002). However, the relationship between staffing levels and work environment has been emphasized (Cho et al., 2016), and staffing levels are associated with outcomes such as failure to rescue, readmission after surgery, pressure ulcers, falls and other adverse events (Aiken et al., 2014; Bae et al., 2010; Kane et al., 2007; Lasater and McHugh, 2016; Stalpers et al., 2015; Tourangeau et al., 2007). Hence, our data add to existing evidence for the relationship between work environment and clinical outcomes.

Our results show that the risk of surgical site infections was lower for patients admitted for an elective procedure in hospitals where the
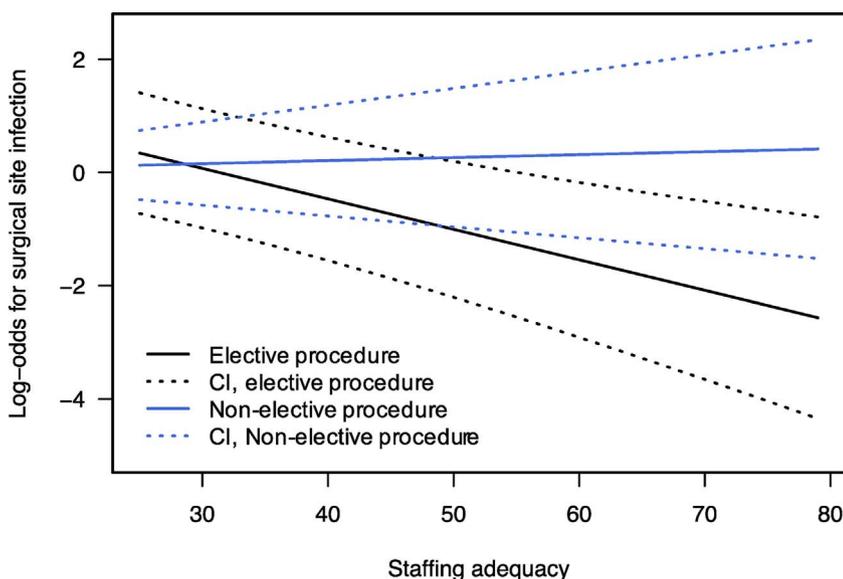
Fig. 1. The relationship between nurse-reported staffing adequacy and log-odds for surgical site infections are shown for elective versus non-elective procedures. The dotted lines show the 95% confidence intervals for the two groups (elective versus non-elective). The reference level for procedure type is non-elective.

nurses' scored the staffing adequacy as high. Patients admitted for an elective procedure are typically elderly persons with adequate cognitive functions who are instructed to prepare for surgery in their homes (e.g. smoking cessation, physical exercise and nutrition and medication advice). There may be an assumption of the organisation or among personnel that these patients will manage well, and as a consequence the patients are left more to themselves. In contrast, elderly patients that are admitted for non-elective procedures may be unprepared (Desserud et al., 2016), and factors such as stabilisation of other medical conditions, regulation of medication, nutrition and mobility might not be optimized prior to admission (Juliebo et al., 2010; Khan et al., 2013). Hence, the instability of these patients may require that they are given special attention even when staffing is not adequate. These differences in patient-related factors for elective versus non-elective patient admissions, may indicate that patients admitted for elective procedures require different strategies than patients admitted for non-elective procedures. Our findings indicate that hospitals are differently organised and prepared for the care of patients admitted for elective versus non-elective procedures.

The most important defense layers for surgical site infection involve preparation of the patients for surgery including antibiotic prophylaxis, stabilization of patients, control of blood sugar levels, temperature etc. (Kunutsor et al., 2016). In addition, the skills of the surgeons as well as the interplay between the surgeons and other staff involved in the surgery is highly important in the perioperative phase (Hawn et al., 2011; Kapadia et al., 2013; Kunutsor et al., 2016). In the present study, the association between surgical site infection and elective procedure might characterise an aspect of the organisational performance. There may be direct connections between organisation of wards and performance in the operating theatre. The preparation of patients before surgery is highly influenced by nurses at the wards, and as already mentioned, nurses are important informants for organisational characteristics. In addition, we know that perceptions, attitudes and behaviour "spread" or interchange between and across work systems through network ties (Christakis and Fowler, 2013), often described as the theory of social contagion that place the individuals or groups in a larger social context. From this point of view, the descriptions of the work environment by one work system (for example nurses) may reflect the work system of other work systems (for example the surgical team) within the same organisation (Braithwaite et al., 2015). The different actors of the work systems such as the ward nurses, the surgical team and the anaesthetic team may share common values and develop common attitudes towards the organisation. The efforts to comply with guidelines may for example be stronger in one hospital compared to another. As exemplified in the introduction the latent conditions of the organisation may be related to factors of the physical environment, the patients, the healthcare personnel, the procedures and administrative controls. Lapses that involve inadequate staffing in any of these layers may compromise the protection against surgical site infection (Reason, 2005; Vincent and Amalberti, 2016). To manage risk in complex organisations, single interventions such as checklists may reduce errors and improve the processes. However, patient safety experts have emphasized that such interventions need to be complemented by strategies that increase resilience and adaption of the system to manage risks and errors. Nurse-reported descriptions of work environment may be an indicator for how well the organisation adapts to manage risks and errors (Hollnagel et al., 2015; Vincent and Amalberti, 2016).

5.1. Limitations of the study

Data from the nurses were based on information from a cross sectional study in 2009, while the NOIS database is a follow-up study including patients from the period from 2005 to 2009. The time span of 5 years was required to obtain sufficient data volume for surgical site infections which is a relatively rare incidence. We cannot rule out that there have been changes in the work environment during the period in which the patients were included. The nurse survey was performed at a time when public attention towards quality and safety was strong, and many hospitals had initiated patient safety interventions. The cross-sectional design of this study did not allow adjustments for variations over time.

Even though the overall response rate for the nurse survey was acceptable, the response rate for some of the hospitals was rather low. However, all hospitals had a response rate above 40%, a cut-off that is considered acceptable for this type of survey (Kramer et al., 2009).

The analyses in the present study could benefit from a more complete risk adjustment for surgical site infection. However, due to systematic errors in the data collection conducted at the hospitals (NOIS), some of these variables were incomplete and were excluded from data analyses. The wards represent a third level that could have been included in the mixed − effects analyses, but we did not have information about the patients' ward affiliation.

6. Conclusion

Our study is among the first to examine the relationship between healthcare associated infections and nurses' work environment. We conclude that the effect of staffing adequacy on surgical site infections depends on whether the patients were admitted for an elective procedure or not. These results add to the existing research that show a linkage between work environment and clinical outcomes. The acknowledgement of this linkage may guide the healthcare management to hold a system perspective in their work towards safer hospitals.

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