Title page

Safe Staffing for Nursing in Emergency Departments: evidence review

Alejandra Recio-Saucedo[1], University of Southampton, Building 67, Highfield, Southampton, SO17 1BJ, A.Recio-Saucedo@soton.ac.uk

Catherine Pope[2],
Chiara Dall'Ora[1],
Peter Griffiths[1],
Jeremy Jones[3],
Robert Crouch[4],
Jonathan Drennan[2]

[1]National Institute for Health Research Collaboration for Leadership in Applied Health Research and Care (Wessex), University of Southampton, Southampton, UK

[2] University of Southampton, Centre for Innovation and Leadership in Health Sciences, Faculty of Health Sciences, Southampton, UK

[3] University of Southampton, Southampton Health Technology Assessment Centre, Faculty of Medicine, Southampton, UK

[4] University Hospitals Southampton NHS Trust, Emergency Department, Southampton, UK

Word count: 3190

Abstract

Objective

Getting staffing levels wrong in hospitals is linked to excess mortality and poor patient experiences but establishing the safe nurse staffing levels in the emergency department (ED) is challenging because patient demand is so variable. This paper reports a review conducted for the National Institute for Health and Care Excellence (NICE) which sought to identify the research evidence to inform UK nursing workforce planning.

Design

We searched ten electronic databases and relevant websites for English language studies published from 1994. Studies included reported a direct measure of nurse staffing relative to an activity measure (e.g. attendances, patient throughput) or an estimate of nurse staffing requirements. Randomized or non-randomized trials, prospective or retrospective observational, cross-sectional or correlational studies, interrupted time-series, and controlled before and after

Results

We identified 16,132 items via databases and 2,193 items through manual and other searching. After title/abstract screening (by one reviewer, checked by a second) 55 studies underwent full assessment by the review team. 18 studies met the inclusion criteria for the NICE review, however 3 simulation studies that reported simulated rather than measured outcomes are not reported here.

Conclusion

The evidence is weak but indicates that levels of nurse staffing in the ED are associated with patients leaving without being seen, emergency department care time and patient satisfaction. Lower staffing is associated with worse outcomes. There remain significant gaps and in particular a lack of evidence on the impact of staffing on direct patient outcomes and adequate economic analyses to inform decisions about nurse staffing. Given that an association between nurse staffing levels and patient outcomes on inpatient wards has been demonstrated, this gap in the evidence about nurse staffing in EDs needs to be addressed.

Introduction

Inadequate staffing levels in hospitals has been linked to excess mortality and poor patient experiences [1-4]. Safe nurse staffing requires that there are sufficient nurses with the required skills to meet patient needs, and that they are organised and managed in a way that enables them to deliver the highest quality of care possible. Establishing a safe nurse staffing level is a key challenge, notably in the Emergency Department (ED) where the acuity and quantity of patient demand is highly variable. Demands on EDs both nationally and internationally are increasing. In England, the number of patients attending consultant-led 24-hour EDs with full resuscitation facilities has risen by approximately 12 per cent [5]. Waiting times in major EDs have also risen: the percentage of patients seen in 4 hours or less fell from 93.5% in 2013/14 to 88.9% in 2014/15. The number of patients waiting on a trolley for admission increased from 33,909 in the winter of 2010/11 to 105,770 in the winter of 2014/15 [6]. These increasing demands have implications for safe staffing nursing requirements.

We conducted an evidence review for the National Institute for Health and Care Excellence (NICE) to identify research that could inform nursing staff requirements to support safe care in EDs across the UK. The review followed established NICE methodology for developing public health guidance [7] and while directed towards UK policy, it includes international evidence to inform global debates about safe nurse staffing.

For the purpose of this review, we defined EDs as consultant-led 24-hour services with full resuscitation facilities and designated accommodation for Accident and Emergency patients (sometimes referred to in the UK as a Type 1 ED). The nursing team was defined as those delivering 'hands on' nursing care to adults and children, to meet fundamental needs and providing technical care, including medication administration and necessary administrative work. Nurse staffing focused on the size and skill mix (number of registered nurses in proportion to healthcare assistants) of the nursing team relative to the number of patients cared for, expressed as nursing hours per patient day (the number of hours

worked by registered nurses and healthcare assistants divided by the number of patient hours over a 24-hour period), nurse patient ratios or an equivalent measure.

Our remit, agreed with NICE, was to review the literature reporting studies at department and organisation level to address six questions:

1. What patient outcomes are associated with safe nurse staffing?
2. What patient factors affect nursing staff requirements (e.g. case mix and volume, acuity, dependency and other risk factors, including psychosocial complexity and safeguarding, informal (family) carer support, triage score and turnover)?
3. What staffing factors affect nursing requirements including services provided by staff who are not part of the core nursing establishment, division of tasks, models of nursing care (e.g. triage, rapid assessment and treatment), nursing experience, skill mix and specialism, transfer duties within the hospital and to external specialist units, nursing team management and administration, proportion of temporary nursing staff, and supervision and teaching?
4. What environmental factors affect nursing staff requirements including availability and physical proximity of other units and specialties/ services, department size and physical layout and department type (e.g. major trauma centre)?
5. What organisational factors influence nursing staff requirements, including availability of other services or assessment models (i.e. medical assessment units, ambulatory facilities or inpatient ward), crowding, management structures, organisational culture, policies, and training?
6. What approaches for identifying nursing staff requirements, including toolkits, are effective, reliable and/or valid and how frequently should they be used?

For all questions we also considered relevant economic evaluations.

Methods

Search strategy

We searched ten electronic databases (Embase, CINAHL, CENTRAL, HTA, CDSR, DARE, NHS EED, NHS Evidence, Econlit, and Medline) and seven relevant websites (American Nurses Association, Royal College of Nursing, Joanna Briggs Institute, Royal College of Emergency Medicine, Society for Acute Medicine, Faculty of Emergency Nursing, Trauma Audit & Research Network). Internet searches for search grey literature and additional citation searching were also undertaken. A list of search terms is provided in the online supplement.

Inclusion criteria

The review covered literature published from 1994**.** To be included, studies had to report a direct measure of nurse staffing (e.g. numbers of nurses on a shift, nursing hours per day) relative to a denominator based on activity (e.g. attendances, patient throughput) as an independent variable or an estimate of nurse staffing requirements as a dependent variable. We considered randomized or non-randomized trials; prospective or retrospective observational studies; cross-sectional or correlational studies; interrupted time-series; controlled before and after studies. We included research published in English, and undertaken in the Organisation for Economic Co-operation and Development (OECD) area (as per the NICE remit)

Studies focused on service redesign or reconfiguration, and those which looked exclusively at other members of the multidisciplinary team, including emergency nurse practitioners (ENP) or advanced nurse practitioners (ANP), were excluded. Likewise, we did not examine studies of single specialty EDs (ophthalmology or dental) or non-consultant (attending) led minor injuries units. Since aggregated findings allow the identification of issues at organisation level, potentially concealing variation at the level of units within organisations, work about nursing workforce planning or recruitment at network, regional or national levels was excluded.

Quality appraisal

A quality appraisal checklist based on the risk of bias assessment for cross-sectional studies published by NICE [7] which was used in a previous review on safe staffing in acute

care settings [8] was used to assess risk of bias. Initial screening consisted of rapid exclusion based on title/abstract completed by one reviewer with a random 10% check by a second researcher. Any disagreements were resolved by recourse to a third independent reviewer. Studies were rated for internal and external validity separately and corroborated by two researchers.

Search results were downloaded into the reference management software Endnote. Data were extracted on study aims, context/setting, research design, sample type and size, patient/nurse level risk adjustment, intervention, outcomes, conclusions. Summary tables of extracted data were produced and synthesized in a narrative form.

Results

We identified 16,132 items via databases and 2,193 items through manual and other searching. After title/abstract screening (by one reviewer, checked by a second) 55 studies underwent full paper assessment and 18 studies met the criteria and were included in the final review (see Figure 1). Three simulation studies that reported simulated rather than measured outcomes are not reported here as we did not have access to details of the primary data collected, analyses and estimated relationships used to develop these simulations.

Figure 1. Study selection flowchart - here

Figure 2 illustrates the dispersed evidence currently available to inform nurse staffing in ED settings. Some studies looked at more than one outcome; most outcomes were examined in single studies, making it difficult to identify trends or meaningful patterns.

Figure 2. range of outcomes measured - here

Below we present the evidence provided by the studies structured around the research questions.

Patient outcomes associated with nurse staffing (review question 1)

Nine studies explored the relationship between outcomes and nurse staffing [9-17] (Table 1). The majority of these (six out of nine studies) were observational studies undertaken in single ED departments, which received between 30,000 - 180,000 patients per year. Seven out of nine studies were completed in the USA. Most of the studies were assessed as high risk of bias, limited on internal (five out of nine) or external validity (eight out of nine). A particular risk of bias associated with many studies was that the relationships reported are influenced by endogeneity (both outcomes and staffing levels are influenced by patient need), which could result in attenuated staffing outcome associations or apparent counter-intuitive results whereby higher staffing levels are associated with worse outcomes. Outcomes reported included patient waiting times, time spent in the ED patients who left without being seen, patient satisfaction, medication errors, time to aspirin or antibiotic administration, and ambulance diversion. The evidence regarding patient waiting times is mixed. However, there is evidence that lower levels of ED staffing are associated with increased levels of patients leaving without being seen. Studies in the USA [11] found short-staffing of registered nurses to be a predictor of a higher number of patients leaving without being seen (OR 2.4, 95% CI 1.3-4.5, $p \leq 0.006$); the number of nursing vacancies (FTE) was strongly correlated with the percentage of patients leaving without being seen ($r = 0.89$, $p = 0.007$) [12] and registered nurses to patient ratio was significantly associated with odds of patient leaving without being seen (OR 6, 95% CI 2.3-15.4) [13].

Time spent in an ED bed before discharge or transfer to an inpatient bed was reported to increase [10] when nurse staff was out-of-ratio (ratios defined as 1:1 for trauma resuscitation patients, 1:2 for critical patients, 1:4 for all other ED patients), with 37% longer care time [95% CI = 34% to 41%, $p < 0.001$] in two sites combined. Increases in nurse staff skill mix was associated with increased patient satisfaction [15]. Longer lengths of stay for patients in ED were associated with an increase in hospital occupancy rates, additional patients admitted to the wards and the number patients admitted to ICU from

the ED [16]. No association was found between ED nurse staffing medication errors, time to antibiotics, ambulance diversion or patients' time in the ED.

Author	Country	Design	No of EDs	Comparisons	Outcome	Key results	Patients Seen (Census)	Internal Validity	External Validity
Brown et al. (2012)[11]	USA	Retrospective observation	1	Actual Compared to Scheduled RN Staffing Hours	Left Without Being Seen	RNs staffing predictor of a higher number of patients leaving without being seen	50,000	-	-
Chan et al. (2009)[14]	USA	Prospective observation	2	Mandated Nurse-Patient ratios compared to Out of ratio care	Time to antibiotic administration	Shorter time to antibiotic administration if nurse staff in-ratio	61,000	+	-
Chan et al. (2010)[10]	USA	Prospective observation	2	Mandated Nurse-Patient ratios compared to Out of ratio care	Waiting Time Emergency Department Care Time	Longer wait times when the ED overall was out-of-ratio. Longer ED care time for patients whose nurse was out-of-ratio.	59,733	+	-
Daniel (2012)[15]	Can	Retrospective observation	107	Nurse-Patient Ratios	Patient Satisfaction	Increase in overall patient satisfaction associated with nurse staff skill mix. Percent of full-time nursing worked hours negatively associated with overall patient satisfaction. Physician and nurse courtesy highly associated with patient satisfaction.	182,022	+	+
Greci et al. (2011)[13]	USA	Cross sectional	1	Staff workload when the ED was crowded and not crowded	Left Without Being Seen Ambulance Diversion	RN:patient ratio significantly associated with patient leaving without being seen. No association with ambulance diversion. RN:patient ratio significantly associated with perception of crowding	30,000	-	-
Hoxhaj et al. (2004)[12]	USA	Retrospective observation	1	Nurse staffing levels	Left Without Being Treated	No. of nursing vacancies (FTE) strongly correlated with percentage of patients who left without being treated. Total monthly nursing hours to monthly ED census ratio strongly correlated with percentage of patients who left without being treated	92,000	-	-
Rathlev et al. (2012)[16]	USA	Time series	1	Number of ED nurses on duty Hospital occupancy Number of patients admitted to the hospital Number of patients admitted from ED to ICU Number of ED resuscitation cases	Length of Stay (LOS)	Numbers of nurses, ED discharges on previous shift, resuscitation cases, and elective surgical admissions not associated with LOS on any shift. LOS reduced per additional nurse (average staff level unclear)	91,643	+	-
Schull et al. (2003)[17]	Can	Retrospective observation	1	Number of patients boarded in the ED. Number of ED nurse hours worked per shift. Number of emergency physicians per shift	Ambulance Diversion	Number of admitted patients boarded in the ED predictor of increased ambulance diversion. ED nurse hours not associated with crowding	37,999	-	-
Weichenthal et al. (2011)[9]	USA	Before & After	1	Nurse-patient ratios	Waiting times, Left without being seen, Medication errors Time to Aspirin Administration Time to Antibiotic Administration	after the introduction of nursing ratios - wait times increased significantly - Percentage of patients who left without being seen decreased -No significant change in reported medication errors after the implementation of nursing ratios - No significant change in the rate of aspirin administration. - for patients with pneumonia, decrease time from written order to administration of antibiotics	59,163 (Before) 55,976 (After)	-	-

Table 1 Patient Outcomes associated with Nurse Staffing*

* Internal/External validity (+,-). The summary bias assessment was completed from a detailed evaluation that considered risk adjustment, data completion and sampling strategy across data sources, outcome types, and levels. Ratings were summarised to give a + for some of the assessment criteria fulfilled and conclusions unlikely to change or – for few criteria fulfilled and conclusions likely to change. During quality assessment, no studies were rated ++ indicating that the method was likely to minimise bias or with conclusions unlikely to change.

Staffing, patient, organisational or environmental factors and nurse staffing requirements (review questions 2-5)

With regards to other staffing, patient, organizational, and environmental factors affecting nurse staff requirements, two studies [18, 19] (Table 2)explored the introduction of a specialist psychiatric nursing service and absenteeism (staffing), one study [20] explored workload and patient acuity (patient factors) and one [21] explored the association between hospital-wide bed capacity, nursing and physician numbers at hospital level and waiting time (organisational factors). All four studies had significant risk of bias due to limitations in internal validity, and three out of four studies were assessed as having limitations in external validity. There were no studies that provided evidence regarding environmental factors.

A US study about task allocation [20] analysed 63 nursing shifts and found that on average registered nurses spent 25.6% of their time performing direct patient care, 48.4% on indirect patient care, 6.8% on non-RN care, and 19.1% on personal time (meal and toilet breaks, reading, non–patient-related conversation). Personal task allocation varied with increasing direct and indirect patient care, with non-RN care remaining relatively constant, and decreasing personal time.

One UK study assessed the impact of a dedicated specialist psychiatric nurse service on patient outcomes using a before and after crossover design, assessed as weak for both internal and external validity [18]. This staffing intervention had no association with waiting times (hospital 1 p = 0.76 and hospital 2 p = 0.76), repeat attendances or patient satisfaction levels for people with mental health problems; however, there was evidence of difference of the referral of patients with mental health problems seen by the psychiatric nurse service when compared to the pre-intervention period. Patients seen by a

psychiatric nurse who were recognized as having mental health problems were more likely to be transferred to a mental health unit than admitted to a medical ward (p<0.001), referred to an outpatient clinic (p=0.027) and less likely to be discharged against medical advice (p=0.001). The study found no association with waiting times, repeat attendances or satisfaction levels for mental health patients.

A retrospective observational study [21], assessed as weak in terms of internal and external validity, modelled the impact of changing organisational variables on patient care time (time between being seen by a doctor and being admitted to hospital). This reported that a 1% change in the mean number of nurses at hospital level was associated with a 2.4% fall in ED waiting time and that an increase of 1% in the bed capacity was associated with a 3% fall in waiting time.

We found no studies regarding the influence of environmental factors such as physical layout on nurse staffing requirements.

Study	Country	Design	Number of EDs	Comparisons	Outcome	Key Results	Patients seen	Internal validity	External validity
Green *et al.* (2013)[19]	USA	Prospective Observational	1	Workload as defined by nurse-patient ratios	Staff Absenteeism	Failure to incorporate absenteeism as an endogenous effect results in understaffing. Nurse absenteeism is exacerbated when fewer nurses are scheduled for a particular shift. No quantitative results were reported	Not stated	-	-
Harris *et al.* (2010)[21]	Aus	Retrospective Observational	38	Annual average of nurses, physicians and beds at hospital level	Patient care time in the ED	A 1% change in the mean number of nurses (from 998 to 1008) is associated with a 2.38% fall in waiting time (from 396 to 3871/49 min) assuming all other variables remain at their mean values.	Not stated	-	+
Hobgood *et al.* (2005)[20]	USA	Prospective Observational	1	Workload (Nurse-patient ratio ED Acuity Index)	Task Allocation	RNs spent 25.6% of their time performing direct patient care; 48.4% on indirect patient care; 6.8% on non-RN care and 19.1% on personal time. The correlation between the ED acuity index and the patient-to-nurse ratio was 0.98.	60,000	-	-
Sinclair *et al.*, (2006)[18]	UK	Before and After	2	Prior to and following the introduction of a specialist psychiatric nursing service	Waiting times Onward referral Repeat attendance Patient satisfaction Staff views	Average waiting times at each hospital shortest during the intervention period. No significant differences between pre-intervention and intervention periods at either site (hospital 1, p=0.763; hospital 2, p=0.076). Significant difference in onward referral patterns between intervention and non-intervention periods of the study at both sites (hospital 1, $\chi2$=28.8, p=0.001; hospital 2, $\chi2$=25.3, p,0.01). Levels of satisfaction recorded were high for all patients with no significant differences between intervention and non- intervention periods.	Dept: 1 = 55,000 Dept: 2 = 70,000	-	-

Table 2 Staffing, patient, organisational or environmental factors and nurse staffing requirements

Effective approaches for identifying nursing staff requirements (review question 6)

Two studies reported on toolkits to determine staffing levels in the ED [22, 23] (Table 3). One [23] compared nursing work required against the actual number of nurses in the shift, but did not provide sufficient information to assess the reliability or validity of the tools used. The second tested the validity, reliability and generalizability of the Jones Dependency Tool (JDT) [22] and identified a significant correlation between the JDT and the nurses' subjective ratings of patient dependency (R = 0.786, p < 0.001). There was a positive relationship between the amount of time spent by nurses in direct care of patients and the patient's level of dependency (R = 0.72, p < 0.001). The study also identified a relationship between JDT scores measured over time (Cohen's Kappa k = 0.68) as well as acceptable levels of inter-rater reliability between the JDT and nurses' subjective rating (k = 0.75). However, there was no external validation other than the subjective rating of staff adequacy and no measure of association with outcomes.

Study	Country	Design	Number of EDs	Comparisons	Outcomes	Results	Patients seen	Internal validity	External validity
Crouch and Williams (2006)[22]	UK	Prospective Observational	6	N/A	Dependency score	The higher the amount of time spent by nurses in direct care of patients the higher the patient's level of dependency (R = 0,72, P < 0.001). Age was significantly associated with dependency - for a 10 year age difference the score increase by 0.51 (95% CI 0.43–0.59). There was a significant correlation between triage rating and Jones Dependency Tool scores (R = 0.58, P < 0.001). Highly significant correlation between the Jones Dependency Tool scores and the nurses' subjective ratings of patient dependency (R = 0.786, P < 0.001).	840	+	-
Korn and Mansfield (2008)[23]	USA	Prospective Observational	1	N/A	N/A	Factors influencing staff requirements were acuity-based norms (time for new admissions and nurse to staff ratios (from 1:2 for ICU to 1:10 for regular admissions) for boarders. Results were model tabulations stating whether ED was "OK" or "Overloaded" based on patient numbers/ acuity and model assumptions.	N/A	-	-

Table 3 Approaches for identifying nursing staff requirements

<u>Discussion</u>

This review identified a number of outcomes that appear to be associated with nurse staffing levels in ED. While the evidence is not strong, it appears to indicate that levels of nurse staffing in the ED are associated with patients leaving without being seen, emergency department care time and patient satisfaction. Lower staffing is associated with worse outcomes. We did not find strong evidence that waiting times, medication errors, and the rate of aspirin administration or ambulance diversion are affected by nurse staffing levels. There is conflicting evidence from two weak studies on the association between nurse staffing and time to antibiotics for patients with pneumonia. There was evidence from one study that patients with mental health problems seen by a dedicated psychiatric nurse in an ED were more likely to be transferred to a mental health unit.

At an organisational level, longer lengths of stay for patients in ED were associated with an increase in hospital occupancy, additional patients admitted to the wards and the number patients admitted to ICU from the ED [16]. One study, [21] identified that increases in the number of nurses and doctors, and bed capacity in a hospital was associated with a reduction in the average waiting time in ED. Another study [20] showed that as workload increased, direct and indirect patient care also increased while personal time decreased. There is no evidence on the effectiveness of toolkits in for identifying staffing requirements although there is a suggestion that the Jones Dependency Tool can be used to determine nursing workload in EDs [22].

The review has some limitations. The focus and scope of the review was determined by the remit provided by NICE and was necessarily tailored to the UK policy environment. Nonetheless our findings and conclusions have relevance beyond this context. We limited our search to studies in English, from OECD countries, and only explored those that reported on the observed associations between staffing levels and patient outcomes. We have not reported on simulation and modeling studies as we did not have access to detail of the primary data or relationships used to develop these. However the three simulation studies we

examined for the larger NICE review do not alter the conclusions offered in this paper. All the studies reviewed were observational, no randomised controlled trials were identified and this is a significant weakness of study design and therefore of the evidence base. Furthermore, research exploring associations between staffing levels and outcomes needs to explore thresholds which might help identify adequate staffing levels, rather than only modelling linear associations.

The patient populations and outcome measures varied across the research reviewed, as did the quality of the included studies, which makes generalization problematic. Synthesis of findings was not possible, in part due to the diverse outcomes studied (see Figure 2). While clearly no single outcome can fully reflect safe and effective staffing in emergency departments, future research would benefit from a more consistent approach to measurement which may include utilisation measures (waiting times and left without being seen), safety measures (for example drug administration errors) and measures of staff wellbeing (job satisfaction and staff turnover).

Conclusion

There remain significant evidence gaps, notably a lack of evidence on the impact of staffing on direct patient outcomes such as mortality, failure to rescue, never events, time to pain assessment or falls. This is in stark contrast to the evidence base for the association between ward based nurse staffing and patient outcomes, which is large and offers strong evidence that lower nurse staffing levels are associated with higher rates of mortality and failure to rescue in North America, Europe and elsewhere [e.g.24, 25-28] although evidence that this relationship is causal and for relationships with other outcomes remains limited. [29] Moreover there is no adequate economic evidence that could inform decision making about nurse staffing in emergency departments. Given compelling evidence of association between nurse staffing levels and patient outcomes on inpatient wards, further research is urgently needed to guide decision making about nurse staffing in EDs.

Acknowledgements

References

1.   Berwick, D., *A promise to learn—a commitment to act. Improving the safety of patients in England. National Advisory Group on the Safety of Patients in England*. 2013, London: Stationery Office.

2.   Francis, R., *Independent inquiry into care provided by mid Staffordshire NHS Foundation Trust January 2005-March 2009*. Vol. 375. 2010: The Stationery Office.

3.   Francis, R., *The Mid Staffordshire NHS Foundation Trust Public Inquiry—Chaired by Robert Francis QC*. Report of the Mid Staffordshire NHS Foundation Trust Public Inquiry. Executive summary. TSO, London, 2013.

4.   Keogh, B., *Review into the quality of care and treatment provided by 14 hospital trusts in England: overview report*. 2013: NHS.

5.   *What's going on in A&E? The key questions answered*. 14 January 2015; Available from: http://www.kingsfund.org.uk/projects/urgent-emergency-care/urgent-and-emergency-care-mythbusters?utm_source=kftwitter&utm_medium=social.

6.   Blunt, I., N. Edwards, and L. Merry, *What's Behind the A&E 'Crisis'?* 2015, Nuffield Trust.

7.   *Methods for the development of NICE public health guidance – third edition (2012)*. 2012, National Institute for Health and Clinical Excellence.

8.   Griffiths, P., et al., *The association between patient safety outcomes and nurse/healthcare assistant skill mix and staffing levels & factors that may influence staffing requirements (NICE Evidence review)*. 2014, NICE: UK.

9.   Weichenthal, L. and G.W. Hendey, *The effect of mandatory nurse ratios on patient care in an emergency department*. Journal of Emergency Medicine, 2011. **40**(1): p. 76-81.

10.   Chan, T.C., et al., *Effect of mandated nurse-patient ratios on patient wait time and care time in the emergency department*. Academic Emergency Medicine, 2010. **17**(5): p. 545-552.

11.   Brown, L., et al., *Impact of nursing short-staffing and emergency department left without being seen*. Annals of Emergency Medicine, 2012. **Conference**(var.pagings): p. 4.

12.   Hoxhaj, S., M.G. Moseley, and C.L. Reese, *Nurse staffing levels affect the number of emergency department patients who leave without treatment*. Academic Emergency Medicine, 2004. **11**(5): p. 459.

13.   Greci, L.S., et al., *CrowdED: crowding metrics and data visualization in the emergency department*. Journal of Public Health Management & Practice, 2011. **17**(2): p. E20-E28.

14.   Chan, T.C., et al., *Impact of mandated nurse-patient ratios on time to antibiotic administration in the emergency department*. Annals of Emergency Medicine, 2009. **Conference**(var.pagings): p. 3.

15.   Daniel, I., *The Relationship between Nurse Staffing and Patient Satisfaction in Emergency Departments*. 2012, University of Toronto (Canada). p. 209.

16.   Rathlev, N.K., et al., *Time series analysis of emergency department length of stay per 8-hour shift*. The Western Journal of Emergency Medicine, 2012. **13**(2): p. 163-168.

17.   Schull, M.J., et al., *Emergency department contributors to ambulance diversion: a quantitative analysis*. Ann Emerg Med, 2003. **41**(4): p. 467-76.

18.   Sinclair, L., et al., *How effective are mental health nurses in A&E departments?* Emergency Medicine Journal, 2006. **23**(9): p. 687-692.

19.   Green, L.V., S. Savin, and N. Savva, *"Nursevendor Problem": Personnel Staffing in the Presence of Endogenous Absenteeism*. Management Science, 2013. **59**(10): p. 2237-2256.

20.   Hobgood, C., J. Villani, and R. Quattlebaum, *Impact of emergency department volume on registered nurse time at the bedside*. Annals of Emergency Medicine, 2005. **46**(6): p. 481-489.

21.   Harris, A. and A. Sharma, *Access block and overcrowding in emergency departments: an empirical analysis*. Emergency Medicine Journal, 2010. **27**(7): p. 508-511.

22. Crouch, R. and S. Williams, *Patient dependency in the emergency department (ED): Reliability and validity of the Jones Dependency Tool (JDT).* Accident and Emergency Nursing, 2006. **14**(4): p. 219-229.
23. Korn, R. and M. Mansfield, *ED overcrowding: an assessment tool to monitor ED registered nurse workload that accounts for admitted patients residing in the emergency department.* J Emerg Nurs, 2008. **34**(5): p. 441-6.
24. Kane, R.L., et al., *The Association of Registered Nurse Staffing Levels and Patient Outcomes: Systematic Review and Meta-Analysis.* Medical Care, 2007. **45**(12): p. 1195-1204 10.1097/MLR.0b013e3181468ca3.
25. Rafferty, A.M., et al., *Outcomes of variation in hospital nurse staffing in English hospitals: Cross-sectional analysis of survey data and discharge records.* International Journal of Nursing Studies, 2007. **44**(2): p. 175-182.
26. Aiken, L.H., et al., *Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study.* Lancet, 2014. **383**(9931): p. 1824-30.
27. Duffield, C., et al., *Nursing staffing, nursing workload, the work environment and patient outcomes.* Applied Nursing Research, 2011. **24**(4): p. 244-255.
28. Griffiths, P., S. Jones, and A. Bottle, *Is "failure to rescue" derived from administrative data in England a nurse sensitive patient safety indicator for surgical care? Observational study.* Int J Nurs Stud, 2013. **50**(2): p. 292-300.
29. Griffiths, P., et al., *The association between patient safety outcomes and nurse/healthcare assistant skill mix and staffing levels and factors that may influence staffing requirements (NICE evidence review).* 2014, University of Southampton Centre for innovation and Leadership in Health Sciences.