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Valuing hospital investments in nursing: multistate matched-cohort study of surgical patients

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Abstract

Background—There are known clinical benefits associated with investments in nursing. Less is known about their value.

Aims—To compare surgical patient outcomes and costs in hospitals with better versus worse nursing resources and to determine if value differs across these hospitals for patients with different mortality risks.

Methods—Retrospective matched-cohort design of patient outcomes at hospitals with better versus worse nursing resources, defined by patient-to-nurse ratios, skill mix, proportions of bachelors-degree nurses and nurse work environments. The sample included 62 715 pairs of surgical patients in 76 better nursing resourced hospitals and 230 worse nursing resourced hospitals from 2013 to 2015. Patients were exactly matched on principal procedures and their

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hospital's size category, teaching and technology status, and were closely matched on comorbidities and other risk factors.

Results—Patients in hospitals with better nursing resources had lower 30-day mortality: 2.7% vs 3.1% (p<0.001), lower failure-to-rescue: 5.4% vs 6.2% (p<0.001), lower readmissions: 12.6% vs 13.5% (p<0.001), shorter lengths of stay: 4.70 days vs 4.76 days (p<0.001), more intensive care unit admissions: 17.2% vs 15.4% (p<0.001) and marginally higher nurse-adjusted costs (which account for the costs of better nursing resources): $20 096 vs $19 358 (p<0.001), as compared with patients in worse nursing resourced hospitals. The nurse-adjusted cost associated with a 1% improvement in mortality at better nursing hospitals was $2035. Patients with the highest mortality risk realised the greatest value from nursing resources.

Conclusion—Hospitals with better nursing resources provided better clinical outcomes for surgical patients at a small additional cost. Generally, the sicker the patient, the greater the value at better nursing resourced hospitals.

INTRODUCTION

Better nursing resources in hospitals have substantial clinical benefits for patients. Lower patient-to-registered nurse (RN) staffing ratios, higher proportions of bachelor's educated RNs (ie, education), higher proportions of RNs to total nursing staff (ie, skill mix) and better nursing work environments are associated with more favourable patient outcomes.[1-8] Less is known about the value (ie, outcomes benefit relative to costs) resulting from investments in nursing.[9-13] Given ubiquitous resource constraints within healthcare organisations, we examine whether there are differential clinical outcomes, costs and value at hospitals characterised by better or worse nursing resources.

We use analytical methods that allow for comparisons of very similar patients in hospitals that are similar with respect to size, teaching status and technological capabilities but that are markedly dissimilar with respect to nursing resources, including staffing, education, skill mix and work environments. By pairing patients who underwent the same surgical procedures in hospitals that differed in their nursing resources and who were otherwise similar with respect to over 30 clinical and demographic variables, we disentangle associations among patient factors, hospital characteristics and nursing resources, and focus on how outcomes and costs differ as a function of nursing resources.

We asked whether surgical patients in hospitals with better nursing resources experience differential outcomes, including mortality, failure-to-rescue, readmissions and costs of care (unadjusted and adjusted for nursing costs), even when accounting for fixed hospital characteristics, like size. We examined differences in outcomes and costs among patients undergoing general, orthopaedic and vascular surgeries, and among patients with varying levels of mortality risk. We determine the extent to which better nursing resources translate into greater value in terms of patient mortality relative to costs of care, thereby providing critical evidence for guiding management, policy and resource allocation decisions for healthcare organisations.

METHODS

Study population

Study participants included Medicare fee-for-service beneficiaries, 65.5 years or older, who were admitted for general, orthopaedic or vascular surgery between 1 January 2013 and 30 September 2015 to an acute care hospital in California, Florida, New Jersey or Pennsylvania. These states were chosen based on availability of secondary data on nursing resources from the RN4CAST-US survey. To determine clinical outcomes and costs of care incurred 30 days from the index admission date, we used Centers for Medicare & Medicaid Services research identifiable files: inpatient, outpatient, carrier (physician part B), hospice, skilled nursing facility, durable medical equipment and the master beneficiary summary file. We excluded admissions where patients had missing age, sex and invalid date of death, or were enrolled in a health maintenance organisation or lacked part B coverage at any point in the 6 months prior to admission.

Patient characteristics

Patients characteristics were identified using the index admission, defined as the first surgical admission in the study period to a study hospital, and a 180-day look-back across all use files (online supplementary appendix 1). Patient characteristics included age, sex, race, transfer-in status, emergent admission, secondary procedure codes and 30 comorbidities. We estimated each patient's probability of death at the time of admission by constructing a 30-day mortality risk model using a 10% random sample of data that did not overlap with our matched sample (online supplementary appendix 2).[14] Propensity scores for care in a hospital with better nursing resources were estimated using all of the matching covariates.[15]

Hospital characteristics

We defined hospitals as having better or worse nursing resources according to four dimensions: patient-to-RN staffing level, per cent of RNs among all nursing personnel (ie, skill mix), RN education and quality of the nurse work environment. These dimensions were constructed from the 2016 RN4CAST-US study, a survey of over 20 000 RNs in four states who reported on organisational features of their hospitals. Nurse responses were aggregated within hospitals. Details of these data are described elsewhere.[16-18]

Nurse staffing is the number of patients per direct care RN on medical–surgical or equivalent units during the RN's last shift. Nurse skill mix is the proportion of RNs to all nursing staff (ie, RNs, licensed practical nurses and unlicensed assistive personnel). Nurse education is the hospital proportion of RNs with a bachelor's degree in nursing or higher. The nurse work environment was measured using the Practice Environment Scale of the Nursing Work Index (PES-NWI), a 31-item scale endorsed by the National Quality Forum.[1920] The PES-NWI is composed of five subscales which measure aspects of hospital environment and resources and include nurse participation in hospital affairs; nursing foundations for quality of care; nurse manager ability, leadership and support of nurses; staffing and resource adequacy; and collegial nurse–physician relations.

Healthcare Cost Report Information System data were used to categorise hospital teaching status and size. Teaching status was defined as non-teaching, <0.05 residents to bed (RB); minor, ≥0.05 and <0.25 RB; and major, ≥0.25 RB. Small hospitals had <250 beds. Large hospitals had ≥250 beds. Hospitals were defined as high technology if they provided major organ transplant or open-heart surgery, as reported in the Medicare Provider of Service file.

Outcomes

Outcome measures were 30-day mortality, 30-day complications,[21] 30-day failure-to-rescue,[22] 30-day readmissions (or death),[5] length of stay, intensive care unit (ICU) admission and ICU length of stay (online supplementary appendix 3). Economic performance was evaluated using two 30-day resource use-based cost measures (ie, 30-day costs and 30-day nurse-adjusted costs, the latter an extension of the former).[5,23] Thirty-day nurse-adjusted cost additionally accounts for hospitals' cost of investing in higher levels of RN staffing and skill mix in the better nursing resourced hospitals. Using national average RN salary data from the Bureau of Labour and Statistics and adjustments for benefits, we adjusted costs to reflect whether each hospital was above or below the average staffing and accounted for salary differences based on skill mix compositions unique to each hospital (online supplementary appendix 4). Patients' costs were adjusted higher or lower based on their hospital's nursing costs per day and multiplied by the patient's length of stay on a general floor.

Both 30-day costs and 30-day nurse-adjusted costs include the costs of resources used both in-hospital and 30 days postadmission. If a rehospitalisation occurred within 30 days of the index admission date, all costs accrued during the readmission (even those beyond 30 days) were included in 30-day costs. Postdischarge emergency department visits within 30 days of admission were also counted. Costs accrued in the hospital were a function of length of stay, level of care (ie, ICU vs general unit), and total relative value units from acute care bills, procedures and anaesthesia (and in the case of 30-day nurse-adjusted costs, the costs of better RN staffing and skill mix). Our resource use-based cost measures have advantages over alternative cost measures such as cost-to-charge ratios, which are based on negotiated pricing agreements between insurers and providers. Instead, our measures of resource use-based costs are calculated using standardised national prices for resources, which enables meaningful comparisons between hospitals with respect to costs and value.

We define value as the difference in 30-day cost between matched patient pairs in better and worse nursing resourced hospitals divided by the difference in 30-day mortality. Consistent with the literature, value was defined only with the 30-day mortality outcome.[5,24] If there was no statistical difference in mortality, then a value estimate could not be defined. Ninety-five per cent CIs for value estimates were derived using the jackknife.[25] Value is reported as the cost associated with a 1% improvement in mortality. Multiplying the value estimate by 100% allows for the value estimate to be interpreted as the cost per life saved. The cost per 1% improvement in mortality is a more useful interpretation of our findings for policymakers who are interested in understanding the *incremental cost* of improving mortality over a population.

Statistical analysis

Defining hospitals with better and worse nursing resources—To define study hospitals as having either better or worse nursing resources, each hospital was assigned a coherence rank score[26,27] based on four dimensions of nursing (ie, RN staffing, skill mix, education and work environment; online supplementary appendix 5). The coherence rank score was calculated by comparing each of 512 hospitals to all other hospitals, with equal importance given to each dimension of nursing. Details of the clinical coherence method are described elsewhere.[26] In brief, hospital *i* was compared with hospital *j*, such that each of the 512 hospitals were assigned a score based on 511 comparisons. If hospital *i* had better nursing across all four dimensions than hospital *j*, it was scored 1; if hospital *i* had worse nursing than hospital *j*, it was scored a −1; and if hospital *i* was better on some dimensions and worse on others, it was scored 0. The score for hospital *i* was then the sum of its 1, 0 and −1 scores when compared with the remaining 511 hospitals, so a score of 511 would mean that hospital *i* was better than all other hospitals on all four dimensions. Hospitals in the top 15% were defined as better nursing resourced hospitals (n=76). Hospitals in the bottom 45% were defined as worse nursing resourced hospitals (n=230). Principal component analysis produced similar results in terms of which hospitals were categorised as better and worse.

Matching algorithm

Each patient admitted to a better nursing resourced hospital was matched to a patient admitted to a worse nursing resourced hospital using Design-Match in R.[28-31] Our algorithm exactly matched pairs on International Classification of Diseases, Ninth Revision (ICD-9) principal procedure code (online supplementary appendix 6), mortality risk quintile and hospital characteristics, including categories for teaching status, size and technology status. Subject to those constraints, we used fine balance and distance minimisation techniques to make the matched pairs as similar as possible on covariates such as continuous risk of 30-day mortality on admission, age, sex, race, emergent admission status, transfer-in status, propensity score for attending a better nursing hospital, 30 comorbidities and continuous measures of the hospital's number of beds and resident-to-bed ratio (online supplementary appendix 1). Outcomes were compared within pairs using the McNemar test for binary outcomes,[32] while continuous outcomes were reported using m-statistics similar to a 1% trim for each tail.[33,34]

RESULTS

Final patient and hospital sample

Our initial sample included 621 587 surgical patients in 512 general acute care hospitals. The focal group consisted of 87 847 surgical patients (22 054 general, 55 645 orthopaedic and 10 148 vascular) in 76 hospitals with better nursing resources. The control group included 212 683 surgical patients (52 886 general, 135 148 orthopaedic and 24 649 vascular) in 230 hospitals with worse resources.

Better nursing resourced hospitals were superior to the worse nursing resourced hospitals on the four nursing characteristics (table 1). For example, RNs in better hospitals cared for 1.5 fewer patients on average (4.30 vs 5.79) than RNs in worse hospitals. Better resourced hospitals had a nursing skill mix that consisted of a greater proportion of RNs, a higher proportion of Bachelor of Science in Nursing-educated RNs and more favourable average ratings of the nurse work environment. Prior to matching on hospital characteristics, better nursing resourced hospitals were, on average, larger and more likely to be major teaching, high technology hospitals (table 1).

Quality of patient matches

From the 87 847 focal cases (ie, patients in the better hospitals), 62 715 cases were matched with control cases (ie, patients in the worse hospitals). Pairs were matched exactly for principal procedure, mortality risk and hospital size category, teaching status category and technology status category, and then balanced on over 30 covariates. Table 2 presents key covariates for the focal and control cases, before and after matching. After matching, standardised differences did not exceed 0.05 SD, better than our desired goal of 0.1–0.2 SDs (online supplementary appendix 7). For example, prior to matching, 83.5% of patients in the better nursing resourced hospitals had hypertension, compared with 87.4% of patients in the worse resourced hospitals. After matching, the per cent of patients with hypertension in the better and worse nursing resourced hospitals were 85.0% and 85.8%, respectively. The standardised difference before matching (−0.11) was substantially reduced after matching (−0.02), indicating balance was achieved for that covariate.

Our matching algorithm required perfect balance on hospital categories for size, teaching status and technology status, as demonstrated by standardised differences of 0.00 (table 2). Through distance minimisation techniques, we further balanced patient pairs within size and teaching status categories using continuous measures of the hospital's number of beds and resident-to-bed ratios. Slight imbalances were observed on these continuous measures; however, our main study findings persisted after conducting postmatch conditional logit models adjusting for continuous measures of hospital size and teaching status (online supplementary appendix 8).

Outcomes

Table 3 presents differences in outcomes among focal patients in the better nursing resourced hospitals and matched control patients in the worse nursing resourced hospitals. Among general surgical patients in better versus worse nursing resourced hospitals, lower 30-day mortality (4.54% vs 5.23%, p=0.003), lower failure-to-rescue (7.34% vs 8.64%, p=0.007) and lower 30-day readmissions (17.86% vs 18.82%, p=0.022) were observed. There were no differences in complications, ICU admission or length of stay among general surgery patients. The paired difference in 30-day costs per patient was marginally higher among focal patients ($428, p 0.048). Accounting for the expense of more RNs in better resourced hospitals, the paired difference in 30-day nurse-adjusted costs was $1300 (p<0.001).

Among orthopaedic patients, 30-day mortality (1.58% vs 1.91%, p<0.001), failure-to-rescue (3.52% vs 4.18%, p<0.001), readmissions (9.19% vs 10.04%, p<0.001) and complications (56.19% vs 58.15%, p<0.001) were lower for patients in better nursing resourced hospitals. Orthopaedic focal patients were significantly more likely to be admitted to the ICU (7.05%

vs 5.93%, p<0.001). Despite observing statistical differences in overall and ICU lengths of stay among focal and control patients, the differences were not clinically meaningful. Overall length of stay was significantly shorter among orthopaedic focal patients, but the actual difference was small (3.68 days vs 3.77 days, p<0.001). The paired difference in 30-day nurse-adjusted costs was $579 (p<0.001).

Vascular patients in better nursing resourced hospitals experienced significantly more complications (66.77% vs 64.76%, p<0.002) and were more likely to be admitted to the ICU (55.52% vs 46.49%, p<0.001). Statistically significant differences were not observed in 30-day mortality (5.09% vs 5.39%, p 0.390), failure-to-rescue (8.96% vs 10.05%, p 0.191) and readmissions (20.06% vs 20.91%, p 0.172); however, the magnitude of the differences in effect sizes between matched pairs in the better and worse nursing resourced hospitals was large. The paired difference in 30-day nurse-adjusted costs was $1349 (p<0.001). The paired differences in costs were marginal when considered in the context of the overall costs. For example, the paired difference in costs of $1349 was roughly 5% of the overall costs for vascular surgery in better nursing resourced hospitals.

Outcomes by patient risk

To examine whether outcomes and costs varied by patient clinical risk on admission, we aggregated the surgical specialty groups. As patient risk increased, patients in better nursing hospitals had better clinical outcomes with only marginally higher costs, as compared with patients in hospitals with fewer nursing resources (table 4). Focal patients—those in the better nursing resourced hospitals—had lower 30-day mortality than their matched controls, with the largest differences observed in patients with the highest clinical risk (10.84% vs 12.32%, p<0.001). Thirty-day complications and failure-to-rescue were lower in focal patients overall, with lower-risk focal patients experiencing significantly less complication than matched controls and higher-risk focal patients experiencing significantly less failure-to-rescue. Focal patients also had lower 30-day readmission overall and in each risk quintile, with the greatest outcome advantage seen in patients with the highest clinical risk. Focal patients in all risk quintiles were more likely to be admitted to the ICU, except those in the highest-risk quintile for whom there were no statistical differences. Differences in overall and ICU length of stay were statistically but not clinically different in the overall group. The greatest difference in length of stay was observed in the lowest clinical risk group, where focal patients stayed 0.14 days less than their matched pairs, or approximately 3.4 fewer hours.

Value

The nurse-adjusted cost per 1% fewer deaths was $2,035, among all surgical patients (table 5) or $203 500 per life saved (multiplying the value estimate by 100 changes the interpretation to the cost per life saved). Among patients with the highest risk of mortality, the nurse-adjusted cost per 1% fewer deaths was considerably smaller at $947, or $94 700 per life saved. The nurse-adjusted costs per 1% fewer deaths among general and orthopaedic surgical patients were $1887 and $1,766, respectively. A value estimate could not be produced among vascular surgical patients for whom statistically significant mortality differences were not found.

Limitations

Our study is cross-sectional, which limits causal inferences. However, studies of nursing and patient outcomes with panel designs show that hospitals that improve nurse education and nurse work environments over time experience more favourable patient outcomes, including lower mortality.[35-37] Also recent research shows in the case of nursing variables studied here that results from cross-sectional research closely approximate findings in a panel study of hospitals.[16] We analysed outcomes and costs of care among Medicare beneficiaries in four large states in the USA, which may not be generalisable to all older adults and international contexts. While our matched-cohort design makes transparent the comparisons between patients in better and worse nursing resourced hospitals, we are only able to match patients on measurable characteristics available in our data, and thus it is possible that we did not account for all the possible explanations for the observed outcomes and cost differences.

We conducted stability analyses to test whether our findings were robust to alternative model specifications. In our main analysis, we allowed patient pairs to be matched across states; however, others have matched within state.[38] Postmatch adjustments for state differences within matched pairs did not account for the lower mortality observed in better nursing hospitals (online supplementary appendix 9). In our main analysis, we assigned the cost of an admission to an intermediate care (or stepdown) unit the same cost as an admission to a general unit, as others have done, since staffing in intermediate care is closer to general units than ICUs.[39] Our stability analysis shows that assigning intermediate care units the same cost as an ICU, or the average of general unit and ICU costs, did not meaningfully change our results (online supplementary appendix 10). In our main analysis, we focused on hospitals that were distinctly different based on their nursing resources: the bottom 45% and top 15% of hospitals. Comparisons of matched patients in the middle 40% of hospitals with mixed nursing resources can be found in online supplementary appendix 11. Patients in the bottom 45% of hospitals had higher mortality *and* higher costs than their matched pairs in the middle 40% of hospitals. Patients in the best 15% of hospitals had slightly higher costs but no significant differences in mortality compared with patients in hospitals with mixed nursing resources. Nursing resources in the middle 40% of hospitals more closely resemble the nursing resources in the top 15% of hospitals than the bottom 45% of hospitals (online supplementary appendix 12). We also examined mortality differences among the most common procedures, but group sizes were too small to be meaningful (online supplementary appendix 13). Lastly, we examined whether patients' dual-eligible status differed between matched pairs, since hospitals serving higher proportions of socioeconomically disadvantaged patients may have fewer resources to invest in nursing. In our matched patient sample, the better nursing resourced hospitals had slightly *more* dual-eligible patients than worse nursing resourced hospitals (17.0% vs 15.8%, online supplementary appendix 7).

DISCUSSION

By creating matched pairs of similar patients undergoing the same surgical procedures in distinctly different types of hospitals (defined by their nursing resources), we identified an advantage for undergoing surgery in hospitals with better nursing resources. Patients in hospitals with better nursing resources experienced lower mortality, complications, failure-to-rescue and readmission, and had shorter lengths of stay with marginally higher costs.

Our characterisation of hospitals with better nursing resources uses four measures of nursing (ie, staffing, skill mix, education and work environment) constructed from a representative sample of staff RNs, an advance on previous research which also identified better nursing as a signal for better surgical patient outcomes.[5] In that study, hospitals with better nursing were defined by Magnet designation, which is a voluntary accreditation and therefore does not include all hospitals with good nursing resources,[4041] and also relied on a measure of nurse staffing (ie, full-time equivalent RNs and licensed practice nurses to number of total beds), which includes non-direct care nursing staff,[5] and likely resulted in an underestimation of nurse staffing.

In this study, we also employed additional restrictions, compared with previous work,[5] by exactly matching patient pairs on characteristics of their hospital, including indicators of size, teaching status and technological capabilities, to disentangle the relationships between better nursing being disproportionately available in larger academic medical centres. It has long been suggested that there is a relationship between hospital characteristics and quality of care,[42] with studies concluding that teaching hospitals are associated with lower mortality for common medical and surgical conditions[43-46]; however, the mechanisms by which teaching hospitals confer better quality have thus far been largely unexplained. Our findings demonstrate that patient outcomes are associated with nursing resources, even after these adjustments for fixed hospital characteristics like teaching status and size.

All hospitals, regardless of size, teaching status or technology capability, employ a workforce primarily composed of bedside RNs. Nurses provide the majority of around-the-clock care to hospitalised patients and are often the first providers to identify and intervene on early warning signs of clinical deterioration and complication. Improving hospital nursing factors by reducing the number of patients an RN cares for, increasing the proportion of RNs to total nursing staff, increasing the proportion of bachelor's educated RNs, supporting RNs' clinical autonomy, encouraging collegial nurse–physician relationships and engaging RNs in the highest levels of leadership are achievable objectives for all types of hospitals.

However, is there a value case for investing in nursing resources? We found that the sickest (and most expensive) surgical patients, those presenting with the poorest health, experienced better outcomes at the better nursing resourced hospitals, including lower mortality, complications, failure-to-rescue and readmissions, with only small differences in costs. Among all general, orthopaedic and vascular surgery patients, the mortality difference between the best and worst resourced hospitals was −0.413%, and costs were $840 higher, a value estimate of $2035 per 1% lower mortality, which translates to $203 500 per life saved. Among the highest-risk patients, the mortality difference was −1.486%, and costs were $1407 higher, a value estimate of $947 per 1% lower mortality, or about $94 700 per life saved. Thus, while all patients experienced a benefit from better nursing resources at modest costs, value was greatest for the highest-risk patients.

Our findings have implications for management and policy decisions regarding the allocation of resources for patients, such as safe nurse staffing ratio mandates. For example, in 2018, Massachusetts voted against a proposal to mandate nurse staffing levels in acute care hospitals in large part due to concerns raised by hospital associations that such a requirement could lower access and quality for patients and be financially untenable for some organisations. Similar concerns have been raised in European countries reluctant to establish a safe nurse staffing standard, even though major multinational studies of European hospitals show the patient outcomes advantage of better nursing resources.[447] These quality and cost concerns are difficult to reconcile with what we observed: hospitals that invested in their nursing resources provided superior outcomes for patients at a nominal difference in cost.

CONCLUSION

Hospitals with better nursing resources—measured by RN staffing, skill mix, proportion of RNs with a bachelor's degree or higher, and nurse work environment—were associated with more favourable patient outcomes, especially among higher-risk patients, even after accounting for differences in hospital size, teaching status and technological capabilities. Somewhat greater costs were observed in better nursing resourced hospitals. Outcomes and costs were generally in line with better value across all levels of risk but displayed the best value in the sickest patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Hospital characteristics

Characteristics	Better nursing resources (n=76 hospitals)	Worse nursing resources (n=230 hospitals)	P value
Patient-to-RN staffing ratio, mean (SD)	4.30 (0.50)	5.79 (1.05)	<0.0001
Nurse skill mix, mean (SD)	0.85 (0.04)	0.78 (0.05)	<0.0001
Proportion of RNs with a BSN or higher (%)	68.0	43.0	<0.0001
Nurse work environment, mean (SD)	3.01 (0.19)	2.68 (0.22)	<0.0001
Size, mean number of beds (SD)	335.76 (197.14)	239.48 (140.17)	<0.0001
Non-teaching, n (%)	31 (41)	134 (58)	0.0114
Minor teaching, n (%)	24 (32)	77 (34)	0.7806
Major teaching, n (%)	21 (28)	19 (8)	<0.0001
High technology, n (%)	53 (70)	88 (38)	<0.0001

Note: Nurse work environment is rated on a scale of 0 (worst)–4 (best).

BSN, Bachelor of Science in Nursing; RN, registered nurse.

Table 2

Selected matched patient and hospital characteristics

Characteristic (per cent unless noted)	Before match Focal cases: In better nursing resourced hospitals (n=87 847)	After match Focal Cases: In better nursing resourced hospitals (n=62 715)	After match Controls: In worse nursing resourced hospitals (n=62 715)	Before match Controls: In worse nursing resourced hospitals (n=2 12 683)	Before match: Standardised difference	After match: Standardised difference
Age (years), mean	75.7	76.3	76.4	76.8	−0.14	−0.01
Male	41.9	41.2	41.2	41.2	0.01	0.00
Black	4.9	3.9	4.7	3.4	0.08	−0.04
Hispanic	9.2	9.8	8.6	4.6	0.18	0.05
Probability of 30-day mortality	2.7	2.9	2.8	3.2	−0.08	0.01
Emergent admission	24.6	28.0	28.6	34.3	−0.21	−0.01
Transfer-in	0.4	0.5	0.6	0.9	−0.06	−0.02
Comorbidities						
Hypertension	83.5	85.0	85.8	87.4	−0.11	−0.02
Diabetes	21.2	22.5	22.4	22.5	−0.03	0.00
Arrhythmia	30.2	29.9	29.7	31.3	−0.02	0.00
COPD	20.2	21.3	21.9	25.6	−0.13	−0.02
Congestive heart failure	15.3	15.7	15.3	16.3	−0.02	0.01
Dementia	11.1	12.6	12.7	13.8	−0.08	0.00
Myocardial infarction	8.9	8.9	9.1	10.3	−0.05	−0.01
Renal failure	5.6	5.7	5.2	5.1	0.02	0.02
Angina	4.3	4.3	4.1	5.8	−0.07	0.01
Hospital characteristics						
Small (<250 beds)	22.0	26.6	26.6	40.9	−0.42	0.00
Large (≥250 beds)	78.0	73.4	73.4	59.1	0.42	0.00
Beds, mean	460.4	407.2	381.2	317.3	0.69	0.12
Non-teaching	42.1	57.0	57.0	63.8	−0.45	0.00
Minor teaching	18.2	25.0	25.0	29.5	−0.27	0.00

Characteristic (per cent unless noted)	Before match Focal cases	After match Focal Cases	After match Controls	Before match Controls	Before match	After match
	In better nursing resourced hospitals	In better nursing resourced hospitals	In worse nursing resourced hospitals	In worse nursing resourced hospitals	Standardised difference	Standardised difference
	(n=87 847)	(n=62 715)	(n=62 715)	(n=2 12 683)		
Major teaching	39.7	17.9	17.9	6.6	0.85	0.00
Resident-to-bed ratio, mean	0.3	0.1	0.1	0.1	0.82	0.08
High technology status	87.7	85.2	85.2	52.3	0.84	0.00

Note: The standardised difference is the difference in means divided by a pooled SD before matching. See online supplementary appendix 1 for a description of the matching algorithm and online supplementary appendix 7 for a complete balance table using all covariates.

COPD, chronic obstructive pulmonary disease.

Table 3

Comparison of outcomes between matched focal and control patients

Outcome	Better nursing resourced hospitals	Worse nursing resourced hospitals		
General surgery				
Number of patients	15 390	15 390		
	%	**%**	**OR (95% CI)**	**P value**
30-day mortality	4.54	5.23	0.84 (0.76 to 0.94)	0.003
30-day complications	70.10	69.62	1.03 (0.97 to 1.09)	0.312
30-day failure-to-rescue	7.34	8.64	0.85 (0.75 to 0.96)	0.007
30-day readmission (or death)	17.86	18.82	0.93 (0.88 to 0.99)	0.022
ICU admission	25.13	25.23	0.99 (0.93 to 1.05)	0.817
	m-estimate	**m-estimate**	**Paired difference (95% CI)**	**P value**
Length of stay (days)	7.31	7.31	0.01 (−0.11 to 0.13)	0.861
ICU length of stay (days)	0.99	1.05	−0.05 (−0.11 to 0.00)	0.070
30-day cost ($)	26 356	25 939	428 (4 to 853)	0.048
30-day nurse-adjusted cost ($)	27 067	25 744	1300 (868 to 1732)	<0.001
Orthopaedic surgery				
Number of patients	39 956	39 956		
	%	**%**	**OR (95% CI)**	**P value**
30-day mortality	1.58	1.91	0.81 (0.73 to 0.91)	<0.001
30-day complications	56.19	58.15	0.91 (0.89 to 0.94)	<0.001
30-day failure-to-rescue	3.52	4.18	0.76 (0.66 to 0.87)	<0.001
30-day readmission (or death)	9.19	10.04	0.90 (0.86 to 0.95)	<0.001
ICU admission	7.05	5.93	1.24 (1.17 to 1.32)	<0.001
	m-estimate	**m-estimate**	**Paired difference (95% CI)**	**P value**
Length of stay (days)	3.68	3.77	−0.09 (−0.12 to −0.06)	<0.001
ICU length of stay (days)	0.14	0.12	0.02 (0.01 to 0.03)	<0.001
30-day cost ($)	16 484	16 254	200 (74 to 326)	0.002
30-day nurse-adjusted cost ($)	16 802	16 183	579 (450 to 708)	<0.001
Vascular surgery				

Outcome	Better nursing resourced hospitals	Worse nursing resourced hospitals		
Number of patients	7369	7369		
	%	**%**	**OR (95% CI)**	**P value**
30-day mortality	5.09	5.39	0.93 (0.80 to 1.09)	0.390
30-day complications	66.77	64.76	1.13 (1.05 to 1.23)	0.002
30-day failure-to-rescue	8.96	10.05	0.89 (0.75 to 1.06)	0.191
30-day readmission (or death)	20.06	20.91	0.94 (0.87 to 1.03)	0.172
ICU admission	55.52	46.49	1.56 (1.45 to 1.68)	<0.001
	m-estimate	**m-estimate**	**Paired difference (95% CI)**	**P value**
Length of stay (days)	5.02	5.03	−0.02 (−0.17 to 0.13)	0.782
ICU length of stay (days)	1.29	1.15	0.14 (0.07 to 0.21)	<0.001
30-day cost ($)	23 824	23 062	716 (136 to 1297)	0.015
30-day nurse-adjusted cost ($)	24 253	22 864	1349 (761 to 1935)	<0.001

Note: P values for outcomes were calculated using McNemar test for binary outcomes and m-statistics for continuous ones.

ICU, intensive care unit.

Table 4

Comparison of outcomes between matched cases in better and worse nursing hospitals across risk quintiles

		Patient risk quintiles of 30-day mortality				
	Overall	Q1 (lowest)	Q2	Q3	Q4	Q5 (highest)
Outcome	**(N=62 715)**	**(n=12 762)**	**(n=12 567)**	**(n=12 741)**	**(n=12 596)**	**(n=12 049)**
30-day mortality (%)						
Better nursing	2.72	0.15	0.20	0.68	2.13	10.84
Worse nursing	3.13	0.11	0.25	0.82	2.61	12.32
Difference	−0.41***	0.04	−0.05	−0.14	−0.48*	−1.49***
30-day complications (%)						
Better nursing	60.84	44.03	46.91	55.14	70.78	88.83
Worse nursing	61.74	47.60	48.78	55.52	70.33	87.84
Difference	−0.90***	−3.57***	−1.87**	−0.38	0.45	0.99*
30-day failure-to-rescue (%)						
Better nursing	5.39	0.44	0.55	1.56	3.58	13.39
Worse nursing	6.24	0.30	0.67	1.92	4.53	15.58
Difference	−0.85***	0.14	−0.12	−0.36	−0.95*	−2.19***
30-day readmission (or death) (%)						
Better nursing	12.59	4.66	6.10	8.95	15.12	28.97
Worse nursing	13.47	5.11	6.38	9.71	15.71	31.35
Difference	−0.88***	−0.45	−0.29	−0.76*	−0.60	−2.37***
ICU admission (%)						
Better nursing	17.18	6.10	8.92	13.95	21.07	36.88
Worse nursing	15.43	4.60	6.64	11.52	19.22	36.24
Difference	1.75***	1.50***	2.28***	2.43***	1.85***	0.65
Length of stay (days) (m-estimate)						
Better nursing	4.70	2.74	2.93	3.75	5.65	8.90
Worse nursing	4.76	2.86	3.02	3.78	5.75	8.87
Difference	−0.06***	−0.14***	−0.08***	−0.02	−0.09	0.05

		Patient risk quintiles of 30-day mortality				
	Overall	**Q1 (lowest)**	**Q2**	**Q3**	**Q4**	**Q5 (highest)**
Outcome	**(N=62 715)**	**(n=12 762)**	**(n=12 567)**	**(n=12 741)**	**(n=12 596)**	**(n=12 049)**
ICU length of stay (days) (m-estimate)						
Better nursing	0.47	0.06	0.12	0.26	0.53	1.68
Worse nursing	0.45	0.05	0.09	0.20	0.54	1.73
Difference	0.02*	0.02***	0.04***	0.04***	0.01	−0.05
30-day cost ($) (m-estimate)						
Better nursing	19 671	13 215	14 750	17 176	22 051	32 925
Worse nursing	19 358	13 160	14 234	16 588	21 808	32 601
Difference	317***	20	467***	515***	212	338
30-day nurse-adjusted cost ($) (m-estimate)						
Better nursing	20 096	13 420	14 986	17 519	22 599	33 769
Worse nursing	19 246	13 156	14 205	16 490	21 636	32 355
Difference	840***	229***	736***	960***	925***	1,407***

Note. Numbers are rounded for display. For binary outcomes, the difference is the difference in rates. For continuous outcomes, the difference is the m-estimate of the typical pair difference. Being nonlinear, the m-estimate of the difference is not the difference of the m-estimates.

* P<0.05

** P<0.01

*** P<0.001.

ICU, intensive care unit.

Table 5

Cost for a 1% improvement in mortality

				30-day cost			Nurse-adjusted 30-day cost		
Patient group	**N pairs**	**30-day mortality diff**	**P value**	**30-day cost diff (95% CI)**	**P value**	**Value estimate (95% CI)**	**30-day cost diff (95% CI)**	**P value**	**Value estimate (95% CI)**
All general, orthopaedic and vascular surgery	62 715	−0.413%	<0.001	$317 ($172 to $461)	<0.001	$767 ($287 to $1248)	$840 ($694 to $987)	<0.001	$2035 ($1083 to $2986)
Risk quintile 1	12 762	0.039%	0.384	$20 (−$109 to $149)	0.762	Undefined	$229 ($97 to $363)	<0.001	Undefined
Risk quintile 2	12 567	−0.048%	0.423	$467 ($288 to $646)	<0.001	Undefined	$736 ($553 to $918)	<0.001	Undefined
Risk quintile 3	12 741	−0.141%	0.192	$515 ($269 to $761)	<0.001	Undefined	$960 ($712 to $1209)	<0.001	Undefined
Risk quintile 4	12 596	−0.484%	0.011	$212 (−$155 to $578)	0.257	$437 (−$426 to $1301)	$925 ($554 to $1296)	<0.001	$1910 ($159 to $3661)
Risk quintile 5	12 049	−1.486%	<0.001	$338 (−$273 to $949)	0.279	$227 (−$198 to $653)	$1407 ($784 to $2030)	<0.001	$947 ($290 to $1604)
All general surgery	15 390	−0.689%	0.003	$428 ($4 to $853)	0.048	$622 (−$127 to $1371)	$1300 ($869 to $1 732)	<0.001	$1887 ($510 to $3265)
All orthopaedic surgery	39 956	−0.328%	<0.001	$200 ($74 to $326)	0.002	$609 ($91 to $1127)	$579 ($450 to $708)	<0.001	$1766 ($726 to $2805)
All vascular surgery	7369	−0.299%	0.390	$716 ($137 to $1297)	0.015	Undefined	$1349 ($761 to $1935)	<0.001	Undefined

Note: The jackknife was used to estimate the SE of the value ratio and then applied to the point estimate of the value using the standard Wald interval (estimate ±1.96×SE). In cases where there was no significant difference in mortality, a value estimate is not produced and has been designated as ‘undefined’. diff, difference.