Association between Nurse Staffing and In-Hospital Bone Fractures: A Retrospective Cohort Study

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Objective. To determine if sufficient nurse staffing reduced in-hospital fractures in acute care hospitals.

Data Sources/Study Setting. The Japanese Diagnosis Procedure Combination inpatient (DPC) database from July 2010 to March 2014 linked with the Surveys for Medical Institutions.

Study Design. We conducted a retrospective cohort study to examine the association of inpatient nurse-to-occupied bed ratio (NBR) with in-hospital fractures. Multivariable logistic regression with generalized estimating equations was performed, adjusting for patient characteristics and hospital characteristics.

Data Collection/Extraction Methods. We identified 770,373 patients aged 50 years or older who underwent planned major surgery for some forms of cancer or cardiovascular diseases. We used ICD-10 codes and postoperative procedure codes to identify patients with in-hospital fractures. Hospital characteristics were obtained from the “Survey of Medical Institutions and Hospital Report” and “Annual Report for Functions of Medical Institutions.”

Principal Findings. Overall, 662 (0.09 percent) in-hospital fractures were identified. Logistic regression analysis showed that the proportion of in-hospital fractures in the group with the highest NBR was significantly lower than that in the group with the lowest NBR (adjusted odd ratios, 0.67; 95 percent confidence interval, 0.44–0.99; $p = .048$).

Conclusions. Sufficient nurse staffing may be important to reduce postsurgical in-hospital fractures in acute care hospitals.

Key Words. Administrative data uses, cohort analysis, nursing, quality of care/patient safety (measurement)

Prevention of inpatient falls is an important issue for acute care hospitals. Reported proportions of inpatient falls have ranged from 1.3 to 8.9 per 1,000 bed-days (Oliver, Healey, and Haines 2010). In addition, 3–5 percent of

in-hospital falls resulted in major injuries such as fractures, cranial trauma, luxation, or death (Schwendimann et al. 2006, 2008). Fall-related injuries have been associated with increased use of health care resources, prolonged length of stay, and discharge to long-term nursing care facilities (Bates et al. 1995; Hill, Vu, and Walsh 2007; Murray, Cameron, and Cumming 2007). Therefore, in-hospital fall-related injuries are one of the most preventable problems within hospitals.

The American Nurses Association regards patient falls as a nursing-sensitive quality indicator, and the National Quality Forum also views patient falls as a national consensus standard for nursing-sensitive care (National Quality Forum 2004; Montalvo 2007). However, previous studies on the relationship between nurse staffing and inpatient falls and fall-related injuries have shown mixed results, with several literature reviews concluding that the evidence did not support a relationship between nurse staffing and inpatient falls and fall-related injuries (Lake and Cheung 2006; Stalpers et al. 2015). The inconsistencies in these results may be attributed to the relatively small sample sizes and different types of nurse staffing measures used in the studies. Several studies have examined the impact of various factors on inpatient falls, including (1) total nursing care hours per patient day or patient shift (Blegen, Goode, and Reed 1998; Blegen and Vaughn 1998; Cho et al. 2003; Dunton et al. 2004; Patrician et al. 2011; He, Dunton, and Staggs 2012; Staggs, Knight, and Dunton 2012); (2) registered nurse (RN) hours per patient day (Blegen and Vaughn 1998; Sovie and Jawad 2001; Cho et al. 2003; Lake et al. 2010; Bae et al. 2014); (3) non-RN hours per patient day (Dunton et al. 2004; Bae et al. 2014; Staggs and Dunton 2014); (4) RN skill mix (Blegen, Goode, and Reed 1998; Cho et al. 2003; Dunton et al. 2004; Patrician et al. 2011; He, Dunton, and Staggs 2012; Staggs, Knight, and Dunton 2012; Bae et al. 2014); and (5) job satisfaction (Choi and Boyle 2013). This variety of measures precludes the results of these studies being compared and synthesized. Furthermore, inpatient fall-related injuries are rarer events than inpatient falls without injuries. Therefore, studies on the association between nurse staffing and inpatient fall-

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related injuries are more difficult to conduct than on the association between nurse staffing and inpatient falls without injuries.

In recent years, most studies on the association between nurse staffing and inpatient falls and fall-related injuries have been conducted using the United States National Database of Nursing Quality Indicators (NDNQI). However, the NDNQI database does not include patient characteristics and other risk factors, and there was insufficient risk adjustment in these studies (Dunton et al. 2004; Lake et al. 2010; He, Dunton, and Staggs 2012; Staggs, Knight, and Dunton 2012; Choi and Boyle 2013; Staggs and Dunton 2014).

In the present study, we used data from a large national inpatient database in Japan to evaluate the association between nurse staffing and inpatient fall-related injuries in acute care hospitals, adjusting for individual-level patient characteristics and risk factors.

METHODS

Data Source

We used data from the Japanese Diagnosis Procedure Combination (DPC) database, the Survey of Medical Institutions and Hospital Report, and Annual Report for Functions of Medical Institutions. The DPC database covers nationwide inpatient administrative claims and discharge data for acute care hospitals in Japan. All 82 academic hospitals in Japan are obliged to participate in the database, but participation of community hospitals is voluntary. The database contains approximately 50 percent of all acute care inpatient data for Japan, and includes the following: unique identifiers of hospitals; patient details (age, sex, body height, and body weight); smoking status (non-smoker or current/past smoker); activities of daily life (ADL) scores at admission; type of admission (planned or urgent); use of ambulance service; primary diagnoses and comorbidities at admission; in-hospital complications using International Classification of Diseases, Tenth Revision (ICD-10) codes and text data in Japanese; discharge status; medical procedures, including types of surgery (Japanese original codes); daily records of drugs and devices used; and dates of admission, discharge, and medical procedures.

Attending physicians are obliged to record all individual patient data for diagnoses and comorbidities with reference to patients' medical charts to optimize the accuracy of the recorded diagnoses. Data entry is linked with reimbursement for health care costs, meaning physicians and hospitals have a strong incentive for compliance.

The Survey of Medical Institutions and Hospital Report is an annual census of hospitals in Japan that investigates the current status of medical institutions. The survey data include structural information for medical institutions such as type of hospital (academic or nonacademic), number of hospital beds, number of intensive care unit (ICU) beds (including adult [medical, surgical, cardiac, neurological, or mixed], neonatal, pediatric, and maternal-fetal ICU), number of physicians, and the number of full-time equivalent (FTE) RN and licensed practical nurses (LPN) in each hospital.

The Annual Report for Functions of Medical Institutions was conducted to help formulate a future medical care provision system in each regional community in Japan (Ministry of Health, Labour and Welfare, Japan 2014). This survey included more detailed structural information for medical institutions than the Survey of Medical Institutions and Hospital Report, such as total inpatient days over 365 days; and number of FTE nursing staff (RN and LPN) in inpatient hospital wards and units, outpatient departments, operating rooms, etc. We linked these survey data to the DPC database using hospital identifiers as the linkage key.

As data were anonymous, informed consent from individual patients for this study was waived. Study approval was obtained from the Institutional Review Board of The University of Tokyo.

Patient Selection

We selected patients aged 50 years or older who underwent planned major surgery for some forms of cancer or cardiovascular disease between July 2010 and March 2014. Surgery types included surgery for intracranial tumor, pharyngeal cancer, breast cancer, respiratory or mediastinal cancer, aerodigestive cancer, genitourinary cancer, and cardiovascular diseases. Patients who had multiple surgeries on the same day were classified into mutually exclusive primary surgery groups according to a hierarchy: surgery for intracranial tumor, cardiovascular diseases, aerodigestive cancer, respiratory or mediastinal cancer, genitourinary cancer, breast cancer, and pharyngeal cancer. We excluded patients who had: (1) multiple surgeries on different days during a single hospitalization; (2) admission via ambulance service; (3) injury at admission (ICD 10 codes S00–S99, T00–T98, V01–V99, W00–W99, X00–X99, and Y00–Y09); (4) malignant neoplasm of bone and articular cartilage (C40–C41, D480), secondary malignant neoplasm of bone and bone marrow (C795), or multiple myeloma and malignant plasma cell neoplasms (C90); (5) any pathological fracture (M484, M80, M844), stress fracture (M484, M843), or bone

fracture in neoplastic disease (M907); (6) cardiopulmonary resuscitation due to risk of rib fracture; and (7) length of hospital stay within 1 day.

The DPC database clearly differentiates comorbidities at admission from complications after admission. We were therefore able to distinguish fractures at admission from in-hospital bone fractures.

Nurse Staffing

In Japan, there are two kinds of nurse licensed, namely RN and LPN, but there is no advanced practice nurse such as nurse practitioner. We used inpatient nurse-to-occupied bed ratio (NBR) as the nurse staffing variable. NBR was defined as the number of inpatient nurses per 100 occupied beds for each hospital. The number of nurses included the FTE RN and LPN at inpatient hospital wards and units, but it did not include nursing assistants. NBR was categorized into quartiles (lowest, lower middle, higher middle, and highest), with an approximately equal number of patients in each group.

Outcomes and Covariates

The DPC database did not include incident or accident reports for inpatient falls. The primary outcome was the occurrence of in-hospital bone fractures identified by ICD-10 codes (in parentheses) and postoperative procedure codes associated with fractures.

In-hospital fractures included fracture of skull and facial bones (S02); fracture of neck (S12); fracture of rib(s), sternum, and thoracic spine (S22); fracture of lumbar spine and pelvis (S32); fracture of shoulder and upper arm (S42); fracture of forearm (S52); fracture at wrist and hand level (S62); fracture of femur (S72); fracture of lower leg including ankle (S82); fracture of foot excluding ankle (S92); fractures involving multiple body regions (T02); fracture of spine (T08); fracture of upper limb (T10); fracture of lower limb (T12); and fracture of unspecified body region (T142).

Postoperative procedure codes associated with fractures included any cast, traction, reduction of fracture, fracture fixation, open surgery for fractures, and arthroplasty. We excluded fracture of rib(s) (S223, S224) after lobectomy and fracture of sternum (S222) after cardiac surgery or resection of mediastinal tumors.

We identified potential confounding factors as patient age, sex, smoking status, body mass index, ADL score for walking on a flat floor, Charlson comorbidity index, comorbid medical conditions related to falls or bone

fracture, and use of drugs. Patient age was categorized as 50–59, 60–69, 70–79, 80–89, and ≥ 90 years. ADL score for walking on a flat floor was classified as independent (score 3); walks with the verbal or physical help of one person (score 2); wheelchair independent (score 1); and immobile (score 0).

Each ICD-10 comorbidity code at admission was converted into a Charlson comorbidity index based on Quan's protocol, which is widely used to weigh the burden of comorbidities in administrative claims database research (Quan et al. 2005).

Comorbid medical conditions related to falls or bone fracture included dementia (F00–F03), Alzheimer's disease (G30), delirium (F05), extrapyramidal and movement disorders (G20–G26), cerebral infarction (I63), sequelae of cerebral infarction (I69), arthritis (M00, M01, M13), arthrosis (M15–M19), rheumatoid arthritis (M05, M06, M790), osteoporosis (M81, M82), epilepsy (G40, G41), and chronic kidney disease (N18) (Buchner and Larson 1987; Nevitt et al. 1989; Graafmans et al. 1996; Wood et al. 2002; Van Doorn et al. 2003; Kanis et al. 2005; Ensrud et al. 2007; Lakatos et al. 2009; Friedman et al. 2010). Patients who underwent chronic hemodialysis were also regarded as having chronic kidney disease. Patients who used drugs for dementia, Parkinsonism, rheumatoid arthritis, osteoporosis (preoperative period), or epilepsy (preoperative period) were regarded as having those conditions.

We assessed the use of drugs during the postoperative period, including neuroleptics or antipsychotics, antidepressants, benzodiazepines, other sedatives, vasodilators, beta-blockers, diuretics, and diabetic medications, as these may be potential confounding factors (see Appendix SA2 for the list of drugs) (Myers et al. 1991; Leipzig, Cumming, and Tinetti 1999; Krauss et al. 2005; Woolcott et al. 2009; Simonson, Han, and Davidson 2011; Berry et al. 2013; Kolla et al. 2013).

Hospital characteristics included physician-to-occupied bed ratio, hospital bed numbers, type of hospital (academic or nonacademic), and ratio of ICU beds to total hospital beds. As ICU beds are usually staffed by one nurse to two or three patients per shift in Japan, hospitals with a higher percentage of ICU beds would be more likely to have a higher nurse staffing ratio.

Statistical Analyses

Patient baseline characteristics were summarized and compared across the four NBR categories using chi-square tests or analysis of variance as appropriate. The proportions of in-hospital bone fractures were compared across NBR categories using a chi-square test.

We examined the association between NBR and in-hospital bone fractures using multivariable logistic regression analyses, with adjustment for patient and hospital characteristics. To account for clustering of patients within hospitals, logistic regression models were fitted with generalized estimating equations (Hanley et al. 2003). We also conducted a separate logistic regression analysis focusing on patients with aerodigestive cancer. Furthermore, as a sensitivity analysis, we analyzed the data using the same statistical model, with NBR as a continuous variable to ensure the robustness of our findings.

We used a significance level of $p < .05$ for all statistical tests, and all reported p values were two-sided. Statistical analyses were conducted using the *Statistical Package for Social Sciences version 22.0* (IBM SPSS Statistics for Windows, Version 22.0; IBM Corp., Armonk, NY, USA) or *Stata/MP version 14* (Stata Corp, College Station, TX, USA).

RESULTS

We identified 770,373 eligible patients from 1,074 hospitals during the study period. Figure 1 shows the algorithm for patient selection. NBR categories were lowest (≤ 79 inpatient nurses per 100 occupied beds), lower middle (80–86), higher middle (87–94), and highest (≥ 95) NBR groups. Patient and hospital characteristics for each of the NBR categories are presented in Table 1. Patients in the lowest NBR group were more likely to receive surgery for breast cancer or aerodigestive cancer; less likely to receive surgery for cardiovascular diseases; more likely to be in hospitals with lower physician-to-occupied bed ratios; less likely to be in academic hospitals; more likely to be in smaller hospitals; and more likely to be in hospitals with a lower ratio of ICU to total hospital beds.

The overall proportion of in-hospital fractures was 0.09 percent. The number and proportion of in-hospital bone fractures by surgery type were as follows: intracranial tumor, 49 (0.25 percent); pharyngeal cancer, 8 (0.14 percent); breast cancer, 95 (0.09 percent); respiratory or mediastinal cancer, 34 (0.03 percent); aerodigestive cancer, 341 (0.10 percent); genitourinary cancer 64 (0.05 percent); and cardiovascular disease, 71 (0.13 percent).

Table 2 shows the number and proportion of in-hospital bone fractures for each NBR group (lowest, 0.11 percent; lower middle, 0.08 percent; higher middle, 0.08 percent; and highest, 0.06 percent). In the subgroup that underwent surgery for aerodigestive cancer, the proportions of in-hospital bone fracture by NBR group were 0.11 percent (lowest), 0.10 percent (lower middle), 0.09 percent (higher middle), and 0.08 percent (highest).

Figure 1: Flowchart of Patient Inclusion and Exclusion Criteria

Table 1: Patient and Hospital Characteristics

	Total	Inpatient Nurse-to-Occupied Bed Ratio (Per 100 Occupied Beds)				p
		Lowest (≤ 79)	Lower Middle (80–86)	Higher Middle (87–94)	Highest (≥ 95)	
No. of patients	770,373	193,042	191,826	192,707	192,798	
Average age, years (standard deviation)	68.7 (9.1)	69.3 (9.2)	68.5 (9.0)	68.6 (9.0)	68.5 (9.0)	<.001
Male sex, %	53.5	53.6	52.7	54.0	53.8	<.001
Charlson comorbidity index, %						
0–2	77.3	76.9	77.7	77.2	77.6	<.001
≥3	22.7	23.1	22.3	22.8	22.4	
Smoking status, %						
Nonsmoker	56.3	58	55.8	56.6	54.9	<.001
Current or past smoker	33.1	32.7	34.0	33.6	32.3	
Missing	10.5	9.3	10.2	9.8	12.8	
Body mass index, %						
<18.5	8.8	8.8	9.0	8.8	8.7	<.001
18.5–22.9	44.2	44.3	44.2	44.4	44.0	
23.0–24.9	20.7	20.9	20.7	20.6	20.7	
25.0–29.9	21	20.9	20.8	21.2	21.2	
≥30	3.3	3.3	3.3	3.3	3.4	
Missing	1.8	1.7	2.0	1.6	2.0	
ADL score for walking on a flat floor, %						
Score 0–2	4.6	5.7	4.0	4.6	4.2	<.001
Score 3	94.4	93.8	94.3	94.6	94.7	
Missing	1.0	0.5	1.7	0.8	1.1	

Continued

Table 1: Continued

	Total	Inpatient Nurse-to-Occupied Bed Ratio (Per 100 Occupied Beds)				p
		Lowest (≤79)	Lower Middle (80–86)	Higher Middle (87–94)	Highest (≥95)	
Comorbid medical conditions, %						
Dementia	0.9	1.1	0.7	0.9	0.8	<.001
Alzheimer’s disease	0.3	0.4	0.3	0.3	0.3	<.001
Delirium	0.5	0.4	0.5	0.5	0.6	<.001
Parkinsonism	1.0	1.0	0.8	1.0	1.0	<.001
Cerebral infarction	1.5	1.4	1.4	1.6	1.6	<.001
Sequelae of cerebral infarction	1.9	2.3	1.8	1.7	1.9	<.001
Arthritis	0.1	0.1	0.1	0.1	0.1	.099
Arthrosis	0.4	0.5	0.4	0.4	0.5	<.001
Rheumatoid arthritis	0.7	0.7	0.7	0.8	0.7	<.001
Osteoporosis	1.5	1.4	1.4	1.7	1.6	<.001
Epilepsy	1.8	1.5	1.8	2.0	2.0	<.001
Chronic kidney disease	2.5	2.2	2.4	2.6	2.7	<.001
Postoperative drugs, %						
Neuroleptics or antipsychotics	10.9	10.7	10.5	11.2	11.3	<.001
Antidepressants	1.8	1.6	1.6	2.1	1.9	<.001
Benzodiazepines	25.8	24.8	25.3	26.6	26.7	<.001
Other sedatives	15.7	15.6	15.9	16.5	14.9	<.001
Vasodilators	24.7	22.8	22.7	26.5	26.8	<.001
Beta-blockers	4.3	3.3	3.8	4.6	5.3	<.001
Diuretics	19.4	17.1	18.3	20	22	<.001
Diabetic medication	7.9	7.4	7.2	8.7	8.3	<.001

Continued

Table 1: Continued

	Total	Inpatient Nurse-to-Occupied Bed Ratio (Per 100 Occupied Beds)				p
		Lowest (≤79)	Lower Middle (80–86)	Higher Middle (87–94)	Highest (≥95)	
Type of surgery, %						
Intracranial tumor	2.5	1.9	2.4	2.7	3.0	<.001
Pharyngeal cancer	0.8	0.5	0.8	0.9	0.9	
Breast cancer surgery	13.8	14.4	14.6	13.1	13.2	
Respiratory or mediastinal cancer	12.8	10.6	13.2	14.1	13.2	
Aerodigestive cancer	45.7	51.7	45.1	43.7	42.4	
Genitourinary cancer	17.1	16.4	17.5	17.1	17.3	
Cardiovascular disease	7.3	4.5	6.4	8.4	10.1	
Surgery for multiple regions, %	0.7	0.6	0.7	0.7	0.6	<.001
Physician-to-occupied bed ratio per 100 beds, median (interquartile range)	33 (26–54)	26 (20–32)	33 (27–45)	35 (29–66)	47 (30–67)	<.001
Academic hospitals, %	31.4	11.7	22.5	42.9	48.6	<.001
Hospital bed size, %						
≤299	9.8	18.4	6.7	5.9	8.1	<.001
300–399	13.5	25.2	11.1	8	9.6	
400–499	14.4	19.5	16.9	8.1	13.1	
≥500	62.3	36.9	65.3	78.0	69.2	
Percent of ICU bed, %						
Low (≤1.31)	33.5	59.5	34.9	21.5	17.9	<.001
Intermediate (1.32–2.92)	33.2	29.8	39.5	38.1	25.3	
High (≥2.93)	33.4	10.6	25.7	40.4	56.8	

Notes: ADL: activities of daily living (score 0, immobile; score 1, wheelchair dependent; score 2, walks with help of one person (verbal or physical)); score 3 (independent). Surgery for multiple regions: patients who had multiple surgeries on the same day. percent of ICU bed: ratio of ICU beds to total hospital beds (ICU beds includes adult [medical, surgical, cardiac, neurologic, or mix], neonatal, pediatric, and maternal-fetal ICU).

Table 2: Proportion of In-Hospital Bone Fractures in Each Inpatient Nurse-to-Occupied Bed Ratio Group

<i>Inpatient Nurse-to-Occupied Bed Ratio (Per 100 Beds)</i>					
	<i>Total</i>	<i>Lowest (≤79)</i>	<i>Lower Middle (80–86)</i>	<i>Higher Middle (87–94)</i>	<i>Highest (≥95)</i>
All patients					
No.	770,373	193,042	191,826	192,707	192,798
In-hospital bone fractures, <i>n</i> (%)	662 (0.09)	215 (0.11)	161 (0.08)	163 (0.08)	123 (0.06)
Type of surgery					
Intracranial tumor					
No.	19,376	3,707	4,676	5,292	5,701
In-hospital bone fractures, <i>n</i> (%)	49 (0.25)	7 (0.19)	17 (0.36)	14 (0.26)	11 (0.19)
Pharyngeal cancer					
No.	5,797	886	1,554	1,707	1,650
In-hospital bone fractures, <i>n</i> (%)	8 (0.14)	1 (0.11)	3 (0.19)	1 (0.06)	3 (0.18)
Breast cancer surgery					
No.	106,556	27,870	28,074	25,187	25,425
In-hospital bone fractures, <i>n</i> (%)	95 (0.09)	56 (0.20)	14 (0.05)	19 (0.08)	6 (0.02)
Respiratory or mediastinal cancer					
No.	98,287	20,388	25,286	27,256	25,357
In-hospital bone fractures, <i>n</i> (%)	34 (0.03)	8 (0.04)	8 (0.03)	12 (0.04)	6 (0.02)
Aerodigestive cancer					
No.	352,119	99,785	86,452	84,158	81,724
In-hospital bone fractures, <i>n</i> (%)	341 (0.10)	106 (0.11)	90 (0.10)	77 (0.09)	68 (0.08)
Genitourinary cancer					
No.	131,633	31,658	33,587	32,959	33,429
In-hospital bone fractures, <i>n</i> (%)	64 (0.05)	20 (0.06)	15 (0.04)	18 (0.05)	11 (0.03)
Cardiovascular disease					
No.	56,605	8,748	12,197	16,148	19,512
In-hospital bone fractures, <i>n</i> (%)	71 (0.13)	17 (0.19)	14 (0.11)	22 (0.14)	18 (0.09)

Table 3 shows the results of the logistic regression analyses for in-hospital bone fractures. In the all-patient analysis, adjusted odds ratios (95 percent confidential intervals) for in-hospital bone fractures with reference to the lowest NBR group were 0.91 (0.62–1.33) in the lower middle NBR group, 0.81 (0.56–1.18) in the higher middle NBR group, and 0.67 (0.44–0.99) in the highest NBR group. (Further details of all of the odd ratios are described in

Table 3: Logistic Regression Analyses of In-Hospital Bone Fractures

	Odds Ratio	95% Confidence Interval	p
All patients			
Lowest NBR group	1.00		
Lower middle NBR group	0.91	0.62–1.33	.627
Higher middle NBR group	0.81	0.56–1.18	.278
Highest NBR group	0.67	0.44–0.99	.048
Aerodigestive cancer surgery patients			
Lowest NBR group	1.00		
Lower middle NBR group	1.19	0.86–1.63	.279
Higher middle NBR group	1.00	0.73–1.38	.973
Highest NBR group	0.96	0.67–1.39	.839

Notes. NBR: Inpatient nurse-to-occupied bed ratio (per 100 occupied beds). Adjusted for age, sex, smoking status, body mass index, activities of daily living score for walking on a flat floor, Charlson comorbidity index, comorbid medical conditions, postoperative drugs, type of surgery (only for all-patient analysis), multiple surgery, and hospital characteristics.

Appendix SA3.) In the subgroup that underwent aerodigestive cancer surgery, patients in the lowest NBR group had more in-hospital bone fractures than those in the highest NBR group, but the difference was not statistically significant.

In a sensitivity analysis, results of inpatient nurse-to-occupied bed ratio (NBR) for continuous variable showed that adjusted odd ratios (95 percent confidence intervals) for in-hospital bone fractures were 0.99 (0.98–0.99, $p = .039$) for each additional 1 NBR. (Further details for sensitivity analysis are described in Appendix SA4.)

DISCUSSION

The present large-scale, retrospective cohort study using a national inpatient database showed that patients in the group with the highest NBR had a significantly lower proportion of postoperative in-hospital bone fractures than the lowest NBR group after adjustment for patient and hospital characteristics.

The overall proportion of in-hospital bone fractures (0.09 percent) was consistent with that found in previous studies (0.05–0.18 percent) (Halfon et al. 2001; Schwendimann et al. 2006; Church et al. 2011). Our exclusion criteria and database system for distinguishing “conditions present on admission” from “conditions acquired in hospital” enabled detection of postoperative in-hospital bone fractures. During the postoperative period, surgical patients may experience temporal loss of muscle function and impairment in

physical movement related to surgical intervention; postoperative pain; or postoperative treatment with surgical drains, intravenous lines, urethral catheter, and oxygen administration. Furthermore, surgical patients need postoperative rehabilitation when they begin ambulation. Postoperative status is considered to be a high risk for falls. The present study suggested that more intensive nursing support during this period may result in a reduced risk of falls and fall-related injuries.

Several previous studies have suggested that higher nurse staffing was significantly associated with a lower number of falls and fall-related injuries (Sovie and Jawad 2001; Dunton et al. 2004; Patrician et al. 2011; He, Dunton, and Staggs 2012; Staggs, Knight, and Dunton 2012). These studies mainly found that higher nursing care hours per patient day were significantly associated with lower fall rates. Our findings are consistent with the existing literature that higher nurse staffing may be associated with lower fall rates. Importantly, most of these studies were limited because they lacked sufficient risk adjustment. Patient falls and fall-related injuries are influenced by several risk factors such as older age, chronic medical condition, cognitive impairment (e.g., delirium and dementia), mobility impairment (e.g., impaired ADL), and specific medications. These risk factors should not be ignored when evaluating the association between nurse staffing and inpatient fall-related injuries. A particular strength of our study was that the outcome was evaluated after adjustment for multiple factors (patient and hospital characteristics). We found that higher nurse staffing remained significantly associated with decreased in-hospital bone fracture after adjustment for patient and hospital characteristics.

The association between a higher nurse staffing and a lower number of in-hospital bone fractures suggests better nurse staffing may improve the working environment for nurses and lead to higher intensity of care, and possibly better quality patient care. Sufficient nurse staffing is therefore important to maintain patient safety. Our results indicate that an NBR increase of about 15 nurses (e.g., from ≤ 79 to ≥ 95 inpatient nurses per 100 occupied beds) may lead to a 50 percent decrease in in-hospital bone fractures (e.g., from 0.11 to 0.06 percent). Furthermore, sensitivity analysis showed that one additional inpatient nurse per 100 occupied beds was associated with 1 percent risk reduction in-hospital bone fracture.

These findings may provide important pointers for health policy makers and hospital administrators to improve patient safety and quality of care with higher nurse staffing. Adequate nurse staffing should be considered to maintain patient safety. However, the absolute risk reduction (0.05 percent) was small. The cost of increasing NBR to reduce in-hospital fractures is an issue

that needs to be further investigated. In general, in-hospital bone fractures are costly, with Nadkarni et al. (2005) reporting that the cost of treating in-hospital, orthopedic fall-related injuries reached around 3100 GBP (Great Britain pounds) per patient during a 3-year period (1 GBP = 1.82 US dollars in 2005). The U.K. National Health Services (2007) conservatively estimated that the direct health care costs of in-hospital fractures accounted for approximately GBP 2.9 million each year (1 GBP = 2.0 US dollars in 2007). In-hospital bone fractures may also result in complaints or litigation (Oliver et al. 2008). Further studies are needed to evaluate the cost-effectiveness of better nurse staffing to prevent in-hospital fractures.

Several limitations of our study should be acknowledged. First, we lacked data about other nurse staffing measures that were used in previous studies, such as nursing care hours per patient day. Briefly, Japanese hospitals' nurse allocation is similar to the U.S. system in that it is organized by each ward/unit. The clustering of type of surgical wards within hospitals was ignored in our study, and the results could be biased by different staffing intensities in each surgical ward. The lack of control for ward type could bias the results by calculating NBR across all-patient severities. Therefore, we adjusted for the ratio of ICU beds to total hospital beds. Second, other important outcomes, including inpatient falls or falls-related minor injuries were not investigated because of data availability. However, we believe that in-hospital bone fractures are the most severe problems that need to be avoided. Third, our analyses lacked data on other possible confounders, including history of falls, visual impairment, and environmental factors (e.g., flooring and lightning). Fourth, recorded diagnoses in retrospective studies are generally less well validated than those in planned prospective cohorts. The rates of in-hospital bone fracture in our study may have been underestimated due to underreporting. Fifth, our study was limited to surgical patients. Previous studies revealed that medical patients were more likely to fall than surgical patients (Hitcho et al. 2004; Bouldin et al. 2013). However, we selected only surgical patients who underwent planned major surgery to improve the homogeneity of the study population. Future studies are needed to examine NBR and in-hospital bone fractures in medical patients. Finally, population representativeness is limited because the DPC database does not include all community hospitals in Japan.

In conclusion, our study showed that better nurse staffing was significantly associated with a lower proportion of in-hospital bone fractures. Our findings imply that sufficient nurse staffing may be important to reduce in-hospital bone fractures in acute care hospitals.

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REFERENCES

- Bae, S. H., M. Kelly, C. S. Brewer, and A. Spencer. 2014. “Analysis of Nurse Staffing and Patient Outcomes Using Comprehensive Nurse Staffing Characteristics in Acute Care Nursing Units.” *Journal of Nursing Care Quality* 29 (4): 318–26.
- Bates, D. W., K. Pruess, P. Souney, and R. Platt. 1995. “Serious Falls in Hospitalized Patients: Correlates and Resource Utilization.” *American Journal of Medicine* 99 (2): 137–43.
- Berry, S. D., Y. Lee, S. Cai, and D. D. Dore. 2013. “Nonbenzodiazepine Sleep Medication Use and Hip Fractures in Nursing Home Residents.” *Journal of the American Medical Association Internal Medicine* 173 (9): 754–61.
- Blegen, M. A., C. J. Goode, and L. Reed. 1998. “Nurse Staffing and Patient Outcomes.” *Nursing Research* 47 (1): 43–50.
- Blegen, M. A., and T. Vaughn. 1998. “A Multisite Study of Nurse Staffing and Patient Occurrences.” *Nursing Economics* 16 (4): 196–203.
- Bouldin, E. L., E. M. Andresen, N. E. Dunton, M. Simon, T. M. Waters, M. Liu, M. J. Daniels, L. C. Mion, and R. I. Shorr. 2013. “Falls among Adult Patients Hospitalized in the United States: Prevalence and Trends.” *Journal of Patient Safety* 9 (1): 13–7.
- Buchner, D. M., and E. B. Larson. 1987. “Falls and Fractures in Patients with Alzheimer-Type Dementia.” *Journal of the American Medical Association* 257 (11): 1492–5.
- Cho, S. H., S. Ketefian, V. H. Barkauskas, and D. G. Smith. 2003. “The Effects of Nurse Staffing on Adverse Events, Morbidity, Mortality, and Medical Costs.” *Nursing Research* 52 (2): 71–9.
- Choi, J., and D. K. Boyle. 2013. “RN Workgroup Job Satisfaction and Patient Falls in Acute Care Hospital Units.” *Journal of Nursing Administration* 43 (11): 586–91.
- Church, S., T. N. Robinson, E. M. Angles, Z. V. Tran, and J. I. Wallace. 2011. “Postoperative Falls in the Acute Hospital Setting: Characteristics, Risk Factors, and Outcomes in Males.” *American Journal of Surgery* 201 (2): 197–202.

- Dunton, N., B. Gajewski, R. L. Taunton, and J. Moore. 2004. "Nurse Staffing and Patient Falls on Acute Care Hospital Units." *Nursing Outlook* 52 (1): 53–9.
- Ensrud, K. E., L. Y. Lui, B. C. Taylor, A. Ishani, M. G. Shlipak, K. L. Stone, J. A. Cauley, S. A. Jamal, D. M. Antonucci, and S. R. Cummings. 2007. "Renal Function and Risk of Hip and Vertebral Fractures in Older Women." *Archives of Internal Medicine* 167 (2): 133–9.
- Friedman, D. E., R. S. Tobias, C. I. Akman, E. O. Smith, and H. S. Levin. 2010. "Recurrent Seizure-Related Injuries in People with Epilepsy at a Tertiary Epilepsy Center: A 2-Year Longitudinal Study." *Epilepsy & Behavior* 19 (3): 400–4.
- Graafmans, W. C., M. E. Ooms, H. M. Hofstee, P. D. Bezemer, L. M. Bouter, and P. Lips. 1996. "Falls in the Elderly: A Prospective Study of Risk Factors and Risk Profiles." *American Journal of Epidemiology* 143 (11): 1129–36.
- Halfon, P., Y. Egli, G. Van Melle, and A. Vagnair. 2001. "Risk of Falls for Hospitalized Patients: A Predictive Model Based on Routinely Available Data." *Journal of Clinical Epidemiology* 54 (12): 1258–66.
- Hanley, J. A., A. Negassa, M. D. Edwardes, and J. E. Forrester. 2003. "Statistical Analysis of Correlated Data Using Generalized Estimating Equations: An Orientation." *American Journal of Epidemiology* 157 (4): 364–75.
- He, J., N. Dunton, and V. Staggs. 2012. "Unit-Level Time Trends in Inpatient Fall Rates of US Hospitals." *Medical Care* 50 (9): 801–7.
- Hill, K. D., M. Vu, and W. Walsh. 2007. "Falls in the Acute Hospital Setting—Impact on Resource Utilisation." *Australian Health Review* 31 (3): 471–7.
- Hitcho, E. B., M. J. Krauss, S. Birge, W. Claiborne Dunagan, I. Fischer, S. Johnson, P. A. Nast, E. Costantinou, and V. J. Fraser. 2004. "Characteristics and Circumstances of Falls in a Hospital Setting: A Prospective Analysis." *Journal of General Internal Medicine* 19 (7): 732–9.
- Kanis, J. A., F. Borgstrom, C. De Laet, H. Johansson, O. Johnell, B. Jonsson, A. Oden, N. Zethraeus, B. Pfleger, and N. Khaltsev. 2005. "Assessment of Fracture Risk." *Osteoporosis International* 16 (6): 581–9.
- Kolla, B. P., J. K. Lovely, M. P. Mansukhani, and T. I. Morgenthaler. 2013. "Zolpidem is Independently Associated with Increased Risk of Inpatient Falls." *Journal of Hospital Medicine* 8 (1): 1–6.
- Krauss, M. J., B. Evanoff, E. Hitcho, K. E. Ngugi, W. C. Dunagan, I. Fischer, S. Birge, S. Johnson, E. Costantinou, and V. J. Fraser. 2005. "A Case-Control Study of Patient, Medication, and Care-Related Risk Factors for Inpatient Falls." *Journal of General Internal Medicine* 20 (2): 116–22.
- Lakatos, B. E., V. Capasso, M. T. Mitchell, S. M. Kilroy, M. Lussier-Cushing, L. Sumner, J. Repper-Delisi, E. P. Kelleher, L. A. Delisle, C. Cruz, and T. A. Stern. 2009. "Falls in the General Hospital: Association with Delirium, Advanced Age, and Specific Surgical Procedures." *Psychosomatics* 50 (3): 218–26.
- Lake, E. T., and R. B. Cheung. 2006. "Are Patient Falls and Pressure Ulcers Sensitive to Nurse Staffing?" *Western Journal of Nursing Research* 28 (6): 654–77.
- Lake, E. T., J. Shang, S. Klaus, and N. E. Dunton. 2010. "Patient Falls: Association with Hospital Magnet Status and Nursing Unit Staffing." *Research in Nursing & Health* 33 (5): 413–25.

- Leipzig, R. M., R. G. Cumming, and M. E. Tinetti. 1999. "Drugs and Falls in Older People: A Systematic Review and Meta-Analysis: I. Psychotropic Drugs." *Journal of the American Geriatrics Society* 47 (1): 30–9.
- Ministry of Health, Labour and Welfare, Japan. 2014. "Reporting System for Functions of Medical Institutions and Formation of Community Health Care Visions" [accessed on February 8, 2016]. Available at <http://www.mhlw.go.jp/english/policy/care-welfare/care-welfare-elderly/dl/140711-01.pdf>
- Montalvo, I. 2007. "The National Database of Nursing Quality Indicators (NDNQI)." *Online Journal of Issues in Nursing* 12 (3): 2 [accessed on October 1, 2015]. Available at <http://www.nursingworld.org/MainMenuCategories/ANAMarketplace/ANAPeriodicals/OJIN/TableofContents/Volume122007/No3Sept07/NursingQualityIndicators.html>
- Murray, G. R., I. D. Cameron, and R. G. Cumming. 2007. "The Consequences of Falls in Acute and Subacute Hospitals in Australia That Cause Proximal Femoral Fractures." *Journal of the American Geriatrics Society* 55 (4): 577–82.
- Myers, A. H., S. P. Baker, M. L. Van Natta, H. Abbey, and E. G. Robinson. 1991. "Risk Factors Associated with Falls and Injuries among Elderly Institutionalized Persons." *American Journal of Epidemiology* 133 (11): 1179–90.
- Nadkarni, J. B., K. P. Iyengar, C. Dussa, S. Watwe, and K. Vishwanath. 2005. "Orthopaedic Injuries Following Falls by Hospital in-Patients." *Gerontology* 51 (5): 329–33.
- National Health Service. 2007. "Slips, Trips and Falls in Hospital Report – Patient Safety Observatory" [accessed on October 1, 2015]. Available at <http://www.nrls.npsa.nhs.uk/resources/?entryid45=59821>
- National Quality Forum. 2004. "National Voluntary Consensus Standards for Nursing-Sensitive Care: An Initial Performance Measure Set" [accessed on October 1, 2015]. Available at http://www.qualityforum.org/Publications/2004/10/National_Voluntary_Consensus_Standards_for_Nursing-Sensitive_Care__An_Initial_Performance_Measure_Set.aspx
- Nevitt, M. C., S. R. Cummings, S. Kidd, and D. Black. 1989. "Risk Factors for Recurrent Nonsyncopal Falls. A Prospective Study." *Journal of the American Medical Association* 261 (18): 2663–8.
- Oliver, D., F. Healey, and T. P. Haines. 2010. "Preventing Falls and Fall-Related Injuries in Hospitals." *Clinics in Geriatric Medicine* 26 (4): 645–92.
- Oliver, D., S. Killick, T. Even, and M. Willmott. 2008. "Do Falls and Falls-Injuries in Hospital Indicate Negligent Care—And How Big Is the Risk? A Retrospective Analysis of the NHS Litigation Authority Database of Clinical Negligence Claims, Resulting from Falls in Hospitals in England 1995 to 2006." *Quality & Safety in Health Care* 17 (6): 431–6.
- Patrician, P. A., L. Loan, M. McCarthy, M. Fridman, N. Donaldson, M. Bingham, and L. R. Brosch. 2011. "The Association of Shift-Level Nurse Staffing with Adverse Patient Events." *Journal of Nursing Administration* 41 (2): 64–70.
- Quan, H., V. Sundararajan, P. Halfon, A. Fong, B. Burnand, J. C. Luthi, L. D. Saunders, C. A. Beck, T. E. Feasby, and W. A. Ghali. 2005. "Coding Algorithms for Defining Comorbidities in ICD-9-CM and ICD-10 Administrative Data." *Medical Care* 43 (11): 1130–9.

- Schwendimann, R., H. Bühler, S. De Geest, and K. Milisen. 2006. "Falls and Consequent Injuries in Hospitalized Patients: Effects of an Interdisciplinary Falls Prevention Program." *BMC Health Services Research* 6: 69.
- . 2008. "Characteristics of Hospital Inpatient Falls across Clinical Departments." *Gerontology* 54 (6): 342–8.
- Simonson, W., L. F. Han, and H. E. Davidson. 2011. "Hypertension Treatment and Outcomes in US Nursing Homes: Results from the US National Nursing Home Survey." *Journal of the American Medical Directors Association* 12 (1): 44–9.
- Sovie, M. D., and A. F. Jawad. 2001. "Hospital Restructuring and Its Impact on Outcomes: Nursing Staff Regulations Are Premature." *Journal of Nursing Administration* 31 (12): 588–600.
- Staggs, V. S., and N. Dunton. 2014. "Associations between Rates of Unassisted Inpatient Falls and Levels of Registered and Non-Registered Nurse Staffing." *International Journal for Quality in Health Care* 26 (1): 87–92.
- Staggs, V. S., J. E. Knight, and N. Dunton. 2012. "Understanding Unassisted Falls: Effects of Nurse Staffing Level and Nursing Staff Characteristics." *Journal of Nursing Care Quality* 27 (3): 194–9.
- Stalpers, D., B. J. de Brouwer, M. J. Kaljouw, and M. J. Schuurmans. 2015. "Associations between Characteristics of the Nurse Work Environment and Five Nurse-Sensitive Patient Outcomes in Hospitals: A Systematic Review of Literature." *International Journal of Nursing Studies* 52 (4): 817–35.
- Van Doorn, C., A. L. Gruber-Baldini, S. Zimmerman, J. R. Hebel, C. L. Port, M. Baumgarten, C. C. Quinn, G. Taler, C. May, and J. Magaziner. 2003. "Dementia as a Risk Factor for Falls and Fall Injuries among Nursing Home Residents." *Journal of the American Geriatrics Society* 51 (9): 1213–8.
- Wood, B. H., J. A. Bilclough, A. Bowron, and R. W. Walker. 2002. "Incidence and Prediction of Falls in Parkinson's Disease: A Prospective Multidisciplinary Study." *Journal of Neurology, Neurosurgery, and Psychiatry* 72 (6): 721–5.
- Woolcott, J. C., K. J. Richardson, M. O. Wiens, B. Patel, J. Marin, K. M. Khan, and C. A. Marra. 2009. "Meta-Analysis of the Impact of 9 Medication Classes on Falls in Elderly Persons." *Archives of Internal Medicine* 169 (21): 1952–60.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Appendix SA1: Author Matrix.

Appendix SA2: List of Drugs.

Appendix SA3: Logistic Regression Model for In-Hospital Bone Fracture Using NBR as a Categorical Variable.

Appendix SA4: Logistic Regression Model for In-Hospital Bone Fracture Using NBR as a Continuous Variable.