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Lower Postsurgical Mortality for Dementia Patients with Better Educated Hospital Workforce

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Abstract

Background/Objectives—Patients with Alzheimer’s disease and related dementias (ADRD) are at higher risk for poor outcomes following surgery. In this study, we investigated whether care in a hospital with more nurses holding at least a Bachelor of Science in Nursing (BSN) degree mitigates some of that risk, and is associated with reduced mortality for patients with ADRD.

Design—Cross-sectional data from 2006–2007 Medicare claims were linked with the Multi-State Nursing Care and Patient Safety Survey of nurses in four states.

Setting—Adult, non-federal, acute care hospitals in California, Florida, New Jersey, and Pennsylvania (n=531).

Participants—Medicare beneficiaries aged 65 and older with and without ADRD undergoing general, orthopedic, or vascular surgery (N=353,333; n=46,163, ADRD; n=307,170, no ADRD).

Measurements—30 day mortality and failure-to-rescue (death following a complication).

Results—Controlling for hospital, procedure, and patient characteristics, we found that each 10% increase in the proportion of BSN nurses was associated with a 4% lower odds of death (OR = 0.96, 95% CI 0.93–0.98) for patients without ADRD, but a 10% lower odds of death (OR = 0.90, 95% CI 0.87–0.94) for patients with ADRD. Each additional 10% of BSN nurses was

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associated with a 5% lower odds of failure-to-rescue (OR = 0.95, 95% CI 0.92–0.98) for patients without ADRD, but a 10% lower odds of failure-to-rescue (OR = 0.90, 95% CI 0.87–0.94) for patients with ADRD.

Conclusion—Surgical patients with coexisting ADRD are more likely to die within 30 days of admission and experience failure-to-rescue compared to patients without ADRD. Having more BSN nurses at the bedside improves the odds of good outcomes for all patients, and has a much greater effect for patients with ADRD.

Keywords

nurse education; workforce; dementia; mortality

Introduction

Patients with Alzheimer's disease and related dementias (ADRD) are at high risk for adverse outcomes during hospitalization,^{1–5} especially following surgery.⁶ While all older adults are at greater risk for postoperative morbidity and mortality than younger patients,⁷ those with ADRD are particularly vulnerable due to high delirium risk,^{8–11} frailty,^{12,13} more comorbidities,^{14–16} mobility limitations,^{3,17,18} nutrition risk,^{3,4,18} and impaired communication.¹⁹ Nurses serve as the primary clinical surveillance system in hospitals and are responsible for monitoring patients and keeping them safe.^{20–26} Because they are at the bedside 24 hours a day, they are best positioned to identify complications and intervene early,^{25,27} something that is particularly important in patients with ADRD who often cannot recognize a problem or clearly signal for help when needed. Nurses are also responsible for maintaining the safety of patients with ADRD in an inpatient environment that can be disorienting.^{28,29}

Over a decade of research has demonstrated that patients cared for in hospitals with more nurses holding a Bachelor of Science in Nursing (BSN) degree or higher have better outcomes including lower mortality,^{30–34} lower failure-to-rescue (death following a complication),^{30,31} fewer readmissions,³³ and reduced length of stay.^{30–33} In this study, we investigated whether care in a hospital with more BSN nurses is associated with better outcomes for surgical patients with ADRD and mitigates some of the risk that coexisting ADRD confers for those patients. First, we examined the direct effects of ADRD and BSN education, separately, on mortality and failure-to-rescue. Then, we examined the interaction effect of ADRD and BSN education on these outcomes to see whether BSN education had a different effect for patients with ADRD compared to patients without ADRD. We hypothesized that having a greater proportion of BSN nurses would be associated with reduced mortality and failure-to-rescue for all patients, but that the effect would be greater for patients with ADRD.

Methods

Design and Data Sources

This was a cross-sectional analysis of linked datasets representing California, Florida, New Jersey, and Pennsylvania hospitals. Datasets included: 2006 and 2007 Medicare Provider

Analysis and Review (MedPAR) data on inpatient hospitalizations, 2006 and 2007 Beneficiary Annual Summary File (BASF) data on Medicare beneficiary demographics, and the 2006 Multi-State Nursing Care and Patient Safety Survey of registered nurses. MedPAR and BASF data are available from the Centers for Medicare and Medicaid Services (CMS).

The nurse survey was aimed at getting extensive detail on elements of nursing care organization across hundreds of hospitals, using nurses as informants. Surveys were mailed to a 50% random sample of licensed registered nurses in New Jersey, 40% random samples in Pennsylvania and California, and a 25% random sample in Florida. Nurses reported where they worked and their responses were aggregated to their employer. The advantage of obtaining data directly from nurse informants is that it yields information on virtually all hospitals of more than 100 beds, thus, avoiding response bias at the hospital level. The survey had a 39% response rate at the nurse level. A survey of 1,300 non-responders yielded a 91% response rate and found no significant differences on variables of interest between responders and non-responders to suggest bias.³⁵ Details of the nurse survey methodology are described elsewhere.³⁰

Study Population

The sample included 353,333 Medicare beneficiaries who underwent general, orthopedic, or vascular surgery in one of 531 hospitals in California, Florida, New Jersey, and Pennsylvania. Patients were included if they met the following criteria: (1) enrolled in Medicare Parts A and B fee for service for 12 months continuously, except in the case of death, (2) aged 65 years or older, (3) discharged from an inpatient hospital stay between January 1, 2006 and October 1, 2007, and (4) had a diagnosis-related group (DRG) classification for general, orthopedic, or vascular surgery. Of all Medicare patients in our study hospitals, approximately 17% of patients without ADRD and 8% of patients with ADRD underwent one of these surgeries. Hospitals were included if outcomes data were present for at least 50 patients, and if there were at least 10 direct care nurses from the hospital represented in the nurse survey.³⁶ The mean number of nurse respondents per hospital in our sample was 66.

Patients were classified as having ADRD if their claims data contained a Chronic Conditions Warehouse (CCW) flag for ADRD. These flags are generated by CMS based on an algorithm that searches for designated International Classification of Diseases Ninth Revision (ICD-9) codes present within a three year lookback window across inpatient, skilled nursing, home health, hospice, and physician claims. The CCW contains flags for both Alzheimer's disease alone and ADRD. We chose to use the ADRD flag because of higher sensitivity with still reasonable specificity for identifying patients with dementia, compared to the flag for Alzheimer's disease alone.³⁷ The CCW flag for ADRD is based on 24 ICD-9 codes that identify Alzheimer's disease, vascular dementia, and frontotemporal dementias, as well as more generic diagnoses for dementias without an underlying disease process specified. To prevent the inclusion of patients who were diagnosed during or after the incident hospitalization, patients in our sample were classified as having ADRD only if the initial date of the CCW flag preceded the hospital admission date.

Variables and Measures

Patient outcomes—Our main outcomes of interest were death within 30 days of hospital admission and failure-to-rescue. Failure-to-rescue is defined as death within 30 days of admission among patients who experienced serious complications.^{38,39} Claims records were scanned to identify 39 different complications based on secondary diagnosis and procedure ICD-9 codes, and DRG codes, using previously established criteria.³⁸

Main predictor variables—Our primary independent variables were ADRD and BSN education. ADRD was a binary variable representing the presence or absence of dementia, which was determined as described above. BSN education was a continuous variable indicating the percentage of nurses per hospital holding at least a BSN degree. This measure was derived from the nurse survey by aggregating to the hospital level individual nurse respondents' report of their highest level of education achieved. We used this hospital-level measure to account for the fact that surgical patients are usually cared for across multiple units during their hospitalization, and because it is less prone to measurement error and potential bias than unit-level measures since it is based on a much larger sample of nurses. The hospital-level measure of the proportion of BSN nurses was highly correlated ($r = 0.86$) with the proportion of BSN nurses on five types of units that typically care for surgical patients: operating room, recovery room, intensive care units, medical-surgical units, and telemetry units. Prior work has demonstrated that this hospital-level measure has substantial predictive validity for measuring the educational composition of nurses across hospitals.^{31,32}

Covariates—In order to reduce confounding that could be introduced by differences in patient risk or severity of illness and structural hospital characteristics that might be associated with either our predictor or outcome of interest, we controlled for a number of factors related to both the patients and hospitals. We used Elixhauser et al.'s risk adjustment method⁴⁰ to incorporate 27 comorbidities (excluding fluid and electrolyte disorders and coagulopathy).^{41,42} We controlled for the individual comorbidities as well as a separate multimorbidity variable indicating the presence of 2 or more comorbidities. Other patient covariates were age and a dummy variable based on DRG code indicating type of surgery. Hospital characteristics were obtained from the American Hospital Association's annual survey of hospital organizational characteristics, and included bed size, teaching status, and technology status. Bed size was a continuous variable representing the number of beds in each hospital. Teaching status was the ratio of medical residents or fellows to hospital beds, and was categorized as nonteaching (no medical residents or fellows), minor teaching ($< 1:4$), or major teaching ($> 1:4$). Technology status was a binary variable representing whether or not the hospital had capacity to perform open-heart surgery or major organ transplantation.

Statistical Analysis

Descriptive statistics were generated to examine characteristics of study hospitals and determine differences between patients with and without ADRD. We then generated a series of logistic regression models to estimate: (1) the unadjusted and adjusted effects of ADRD on our outcomes; (2) the unadjusted and adjusted effects of BSN education on our outcomes; and finally, (3) the interaction effects of ADRD and BSN education on our outcomes in

models fully adjusted for patient and hospital characteristics. The first two model categories allowed us to identify if there were (separately) outcomes differences across hospitals with different levels of nurse education or across patients with and without ADRD. The final model allowed us to answer the primary research question of whether the effect of education is similar for patients with and without ADRD. Using the estimates from our fully adjusted interaction model, we then plotted predicted probabilities of mortality and failure-to-rescue at varying proportions of BSN nurses for hospitals so that we could identify what the implications might be for ADRD patients if they were to receive care at hospitals with varying levels of nurse education. Data were analyzed using Stata 15.0 (Stata Corp., College Station, TX). This study was approved by the University of Pennsylvania Institutional Review Board.

Results

Table 1 depicts characteristics of the 531 hospitals in our sample. The proportion of nurses holding a BSN degree or higher varied across hospitals, ranging from 0 to 73.9%, with a mean of 38.5% and median of 38.0%. Hospitals with higher proportions of BSN nurses tended to be larger, major teaching hospitals, and high technology facilities.

Compared to surgical patients without ADRD, surgical patients with ADRD were on average older, had more comorbidities, experienced more post-operative complications, and had longer lengths of stay (Table 2). Patients with ADRD were more likely to experience complications including psychosis, seizure, pneumonia and respiratory compromise, gastrointestinal bleed and blood loss, sepsis, gangrene and amputation, renal dysfunction, and decubitus ulcer (Supplementary Table S1). Surgical patients with ADRD had an overall mortality rate of 8.0% and failure-to-rescue rate of 11.6%, compared to a mortality rate of 2.8% and failure-to-rescue rate of 7.1% for surgical patients without ADRD.

The first two columns of Table 3 show odds ratios representing the direct effects of ADRD and BSN education, separately, on 30 day mortality and failure-to-rescue. Controlling for hospital, procedure, and patient characteristics, surgical patients with ADRD were 88% more likely to die within 30 days of admission (OR = 1.88, 95% CI 1.78–1.98), and 53% more likely to experience failure-to-rescue (OR = 1.53, 95% CI 1.45–1.62) compared to patients without ADRD. For all surgical patients, each 10% increase in the proportion of nurses holding a BSN or higher degree was associated with a 6% lower odds of death (OR 0.94, 95% CI 0.92–0.97) and a 6% lower odds of failure-to-rescue (OR 0.94, 95% CI 0.91–0.96).

The last column in Table 3 shows odds ratios representing the interaction effect of ADRD and BSN education on our outcomes. Although receiving care in a hospital with a greater proportion of BSN nurses was significantly associated with 30 day mortality and failure-to-rescue for all surgical patients, our interaction models suggest that patients with ADRD are more sensitive to the variation in BSN education. Controlling for hospital, procedure, and patient characteristics, we found significant interactions between BSN education and ADRD for both mortality (OR 0.95, 95% CI 0.91–0.99) and failure-to-rescue (OR 0.95, 95% CI 0.91–1.00). We then used the interaction effects to compute the odds ratios for 30 day

mortality and failure-to-rescue for surgical patients with and without ADRD. We found that each 10% increase in the proportion of BSN nurses was associated with a 4% lower odds of death (OR = 0.96, 95% CI 0.93–0.98) and 5% lower odds of failure-to-rescue (OR = 0.95, 95% CI 0.92–0.98) for surgical patients without ADRD. However, for surgical patients with ADRD, each additional 10% in the proportion of BSN nurses was associated with a 10% lower odds of death (OR = 0.90, 95% CI 0.87–0.94), and a 10% lower odds of failure-to-rescue (OR = 0.90, 95% CI 0.87–0.94).

To help put these odds ratios into context, Figure 1 depicts the change in predicted probabilities of death and failure-to-rescue for patients with and without ADRD at hospitals with varying proportions of BSN nurses. To the degree that these relationships are indeed causal, these findings suggest that an increase in the proportion of BSN nurses within a hospital from 20% to 80% would be associated with 7 fewer deaths and 17 fewer cases of failure-to-rescue per 1,000 patients without ADRD. However, this same change in the proportion of BSN nurses would be associated with 35 fewer deaths and 51 fewer cases of failure-to-rescue per 1,000 patients with ADRD.

Discussion

Our analysis sought to determine whether having a greater proportion of BSN nurses could mitigate some of the heightened mortality risk that surgical patients with ADRD experience. We found that while all patients benefitted from being cared for in hospitals with more BSN nurses, the effect was greatest for patients with ADRD. For both 30 day mortality and failure-to-rescue, surgical patients with ADRD had greater reduction in odds of each outcome with each additional 10% of BSN nurses compared to patients without ADRD. Our results for all patients combined were similar to what has been previously reported in the literature.^{31,32}

Patients with ADRD are a particularly vulnerable and clinically complex population who require close surveillance and diligent nursing care to prevent unwanted complications and intervene quickly when complications arise. In our study, patients with ADRD were older, had more comorbidities, longer lengths of stay, and experienced more complications compared to patients without ADRD. Because of this complexity, patients with ADRD require care from nurses who are able to think critically, synthesize and analyze large amounts of information, problem solve, and coordinate multiple aspects of care with interdisciplinary colleagues. BSN degree programs emphasize these competencies and, thus, may better prepare nurses to care for these frail and vulnerable patients.⁴³

Surgical patients with ADRD experience more complications, demonstrating their clinical complexity. This increased clinical complexity translates to greater costs, with average inpatient expenditures for Medicare beneficiaries with ADRD surpassing those of beneficiaries without ADRD by more than three-fold.¹⁶ Our results suggest that even once patients with ADRD develop complications, they are less likely to die in hospitals that have more BSN nurses, even controlling for other hospital characteristics like teaching and technology status.

One complication that was particularly prevalent among patients with ADRD was psychosis — this affected only 1% of patients without ADRD, but nearly 18% of patients with ADRD. Delirium, a common cause of psychosis, increases morbidity and mortality in patients with ADRD^{8–11} and provides a good example of how comprehensive nursing care can mitigate risk. Nursing interventions including risk assessment, environmental modifications, early mobilization, reorientation, nutritional support, and other individualized interventions can both help to reduce the incidence of delirium and minimize its effects when it occurs.^{44,45} Similarly, close surveillance and nursing interventions can prevent or reduce the impact of other complications patients with ADRD are likely to experience such as pneumonia, pressure ulcers, and falls.^{25,44,46,47} This suggests that the role of the nurse is not only to prevent complications, but also to protect the patient against further deterioration when a complication arises.

In 2010, the Institute of Medicine released its landmark *Future of Nursing* report⁴³ which recommended increasing the percentage of nurses with BSN degrees in the workforce to 80% by the year 2020. One of the primary arguments behind this recommendation was to prepare the nursing workforce to address the growing complexity of patient needs and care environments in an aging population facing increasing challenges from chronic disease. Our findings support this argument by demonstrating that a patient population known to be vulnerable and clinically complex is particularly sensitive to variation in BSN education.

Limitations of our study include its cross-sectional design, which prevents us from drawing conclusions about causality between BSN education and mortality in this patient population. Additionally, we are using older data, though we have no reason to suspect that the relationship between BSN education and mortality has changed over time. Indeed, the relationship between these variables has remained fairly consistent across different time points and settings in other studies.^{30–32,34} We also relied on claims data to identify clinically-diagnosed dementia which may have resulted in some false-positive and false-negative ADRD diagnoses being included in our sample. While there remains debate as to which diagnostic criteria are appropriate for dementia,¹⁶ the CCW algorithm for ADRD was validated against clinically diagnosed dementia cases in the Aging Demographics and Memory Study cohort of the Health and Retirement Study, and had a sensitivity of 0.85 and specificity of 0.89.³⁷ Finally, we were unable to control for functional impairment in our sample based on the data sources we used. Functional impairment is an important component of frailty,¹³ which itself is an independent predictor of postoperative complications.¹² There are, however, few variables available in administrative claims data to measure this.⁴⁸ To account for added patient complexity beyond the individual comorbidities, we controlled for multimorbidity which is also a determinant of frailty.⁴⁹

In conclusion, surgical patients with ADRD are more likely to die within 30 days of admission and experience failure-to-rescue compared to surgical patients without ADRD. Being cared for in a hospital with more BSN nurses is associated with lower odds of 30 day mortality and failure-to-rescue for all patients; the effect of BSN education is strongest, however, for patients with ADRD. As the population ages, hospitals will be faced with the challenges of caring for a rising number of vulnerable and clinically complex patients with ADRD. Our findings suggest that transitioning to a largely BSN workforce, as

recommended by the Institute of Medicine, would contribute to improved surgical outcomes for this population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Impact statement

We certify that this work is novel. To our knowledge, this is the first study to examine the effects of clinician education on surgical outcomes for patients with Alzheimer's disease and related dementias.

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Figure 1.

Panel A Predicted probabilities of 30 day mortality for surgical patients with and without Alzheimer's disease and related dementias at varying levels of BSN staffing

Panel B: Predicted probabilities of failure-to-rescue for surgical patients with and without Alzheimer's disease and related dementias at varying levels of BSN staffing

Table 1

Study Hospital Characteristics (N=531)

Characteristic	All hospitals		Percentage of hospital nurse workforce with BSN degree or higher
	n	(%)	Mean(%) $\pm$ SD
State			
New Jersey	69	(13.0)	39.0 $\pm$ 11.3
Pennsylvania	134	(25.2)	33.9 $\pm$ 13.2
Florida	137	(25.8)	34.9 $\pm$ 13.5
California	191	(36.0)	41.3 $\pm$ 13.1
Technology status			
High	249	(46.9)	40.3 $\pm$ 12.5
Low	282	(53.1)	35.0 $\pm$ 13.6
Teaching status			
Major	41	(7.7)	48.0 $\pm$ 12.3
Minor	216	(40.7)	36.6 $\pm$ 13.0
Non-teaching	274	(51.6)	36.6 $\pm$ 13.1
Number of beds			
Large (>250 beds)	240	(45.2)	41.4 $\pm$ 12.8
Small ($\leq$ 250 beds)	291	(54.8)	34.3 $\pm$ 13.0
All hospitals			38.5 $\pm$ 13.2

BSN indicates bachelor of science in nursing. Percentages may not sum to 100% because of rounding.

Table 2

Patient Characteristics (N=353,333)

Characteristic	All Patients (n = 353,333)			Alzheimer's Disease & Related Dementias (n = 46,163)		p-value
	n (%)	n (%)	n (%)	n (%)	n (%)	
Age (y), mean ± SD	77.1 ± 6.4	80.6 ± 6.6	76.6 ± 6.2			<.001
Deaths within 30 d of admission	12,369 (3.5)	3,680 (8.0)	8,689 (2.8)			<.001
Complications	127,537 (36.1)	25,688 (55.7)	101,849 (33.2)			<.001
Failure-to-rescue	10,185 (8.0)	2,987 (11.6)	7,198 (7.1)			<.001
Male	135,175 (38.3)	14,932 (32.4)	120,243 (39.2)			<.001
Length of stay (days), median (IQR)	4 (3)	5 (4)	4 (3)			
2 or more comorbidities	215,437 (61.0)	32,303 (70.0)	183,134 (59.6)			<.001
Comorbidities						
Congestive heart failure	34,582 (9.8)	7,325 (15.9)	27,257 (8.9)			<.001
Cardiac arrhythmias	69,362 (19.6)	11,285 (24.5)	58,077 (18.9)			<.001
Valvular disease	30,320 (8.6)	4,488 (9.7)	25,832 (8.4)			<.001
Pulmonary circulation disorders	4,161 (1.2)	619 (1.3)	3,542 (1.2)			.001
Peripheral vascular disorders	18,518 (5.2)	2,967 (6.4)	15,551 (5.1)			<.001
Hypertension, uncomplicated	196,214 (55.5)	22,310 (48.3)	173,904 (56.6)			<.001
Hypertension, complicated	24,921 (7.1)	4,640 (10.1)	20,281 (6.6)			<.001
Paralysis	1,381 (0.4)	191 (0.4)	1,190 (0.4)			.409
Other neurological disorders	11,431 (3.2)	4,323 (9.4)	7,108 (2.3)			<.001
Chronic pulmonary disease	63,950 (18.1)	9,384 (20.3)	54,566 (17.8)			<.001
Diabetes, uncomplicated	59,641 (16.9)	7,933 (17.2)	51,708 (16.8)			.062
Diabetes, complicated	9,758 (2.8)	1,682 (3.6)	8,076 (2.6)			<.001
Hypothyroidism	46,273 (13.1)	6,165 (13.4)	40,108 (13.1)			.079
Renal failure	27,412 (7.8)	5,379 (11.7)	22,033 (7.2)			<.001
Liver disease	4,939 (1.4)	604 (1.3)	4,335 (1.4)			.071
Peptic ulcer disease	2,129 (0.6)	264 (0.6)	1,865 (0.6)			.351
AIDS/HIV	53 (0.02)	8 (0.02)	45 (0.01)			.680
Lymphoma	2,226 (0.6)	256 (0.6)	1,970 (0.6)			.021
Metastatic cancer	9,176 (2.6)	819 (1.8)	8,357 (2.7)			<.001

Characteristic	All Patients (n = 353,333)		Alzheimer's Disease & Related Dementias (n = 46,163)		No Dementia (n=307,170)		p-value
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	
Solid tumor without metastasis	6,780 (1.9)	750 (1.6)	6,030 (2.0)	<.001			
Rheumatoid arthritis / collagen vascular disorders	11,103 (3.1)	1,161 (2.5)	9,942 (3.2)	<.001			
Obesity	17,656 (5.0)	891 (1.9)	16,765 (5.5)	<.001			
Weight loss	6,075 (1.7)	1,782 (3.9)	4,293 (1.4)	<.001			
Blood loss anemia	7,482 (2.1)	1,327 (2.9)	6,155 (2.0)	<.001			
Deficiency anemia	4,267 (1.2)	791 (1.7)	3,476 (1.1)	<.001			
Alcohol abuse	3,707 (1.1)	650 (1.4)	3,057 (1.0)	<.001			
Drug abuse	2,718 (0.8)	541 (1.2)	2,177 (0.7)	<.001			
Psychoses	2,002 (0.6)	1,001 (2.2)	1,001 (0.3)	<.001			
Depression	19,708 (5.6)	4,769 (10.3)	14,939 (4.9)	<.001			

Odds Ratios Estimating the Effects of Alzheimer's Disease and Related Dementias (ADRD) and Nurse Education on Mortality and Failure to Rescue

Table 3

Patient Outcomes	Direct Effect Model: ADRD only		Direct Effect Model: BSN education only		Interaction Model: ADRD x BSN Education	
	OR (95% CI)	P-Value	OR (95% CI)	P-Value	OR (95% CI)	P-Value
30 day surgical mortality						
ADRD	1.87 (1.78–1.97)	<.001	-	-	2.31 (1.95–2.75)	<.001
BSN education *	-	-	0.94 (0.92–0.97)	<.001	0.96 (0.93–0.98)	.002
ADRD X BSN interaction	-	-	-	-	0.95 (0.91–0.99)	.01
Failure to rescue						
ADRD	1.53 (1.45–1.62)	<.001	-	-	1.83 (1.55–2.18)	<.001
BSN education	-	-	0.94 (0.91–0.97)	<.001	0.95 (0.92–0.98)	.002
ADRD X BSN interaction	-	-	-	-	0.95 (0.91–1.00)	.03

* Odds ratios indicate the change in the risk of mortality or failure to rescue (deaths in patients with serious complications) associated with a 10% increase in the proportion of nurses with at least a bachelor of science in nursing (BSN) degree or higher

Patient characteristics: age, comorbidities, multimorbidity, diagnosis-related group. Hospital characteristics: size, teaching status, technology status.

All models account for clustering of patients within hospitals. This analysis included 353,333 patients in 531 hospitals.

CI indicates confidence interval; OR, odds ratio.