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Impact of Dementia on Incidence and Severity of Postoperative Pulmonary Complications Following Hip Fracture Surgery Among Older Patients

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Abstract

Postoperative pulmonary complications (PPCs) are the leading cause of death following hip fracture surgery. Dementia has been identified as a PPC risk factor that complicates the clinical course. By leveraging electronic health records, this retrospective observational study evaluated the impact of dementia on the incidence and severity of PPCs, hospital length of stay, and postoperative 30-day mortality among 875 older patients (≥ 65-year-old) who underwent hip fracture surgery between October 1, 2015 and December 31, 2018 at a health system in the southeastern United States. Inverse probability of treatment weighting using propensity scores was utilized to balance confounders between patients with and without dementia to isolate impact of dementia on PPCs. General linear models revealed that dementia did not have a statistically significant impact on the incidence and severity of PPCs or postoperative 30-day mortality. However, dementia significantly extended hospital length of stay by an average of 1.37 days.

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Keywords

Dementia; hip fracture; postoperative pulmonary complications; inverse probability of treatment weighting (IPTW)

INTRODUCTION

As the baby boomers age and the older adult population rapidly grows in the United States (U.S. Census Bureau, 2020), the incidence of hip fractures in older adults with dementia is becoming more prevalent (Seitz et al., 2011). Over 350,000 Americans were hospitalized for hip fractures in 2018, and the average estimated cost per case was approximately $75,000 (AHRQ, n.d.). The vast majority of hip fractures in older adults occur as a consequence of falling directly on the greater trochanter of the proximal femur (Parkkari et al., 1999). Overall, inpatients with hip fractures are twice as likely to be women than men, and their average age of overall inpatients with hip fractures is 77.5-years (AHRQ, n.d.).

Hip fracture is associated with significant morbidity and mortality, and the leading cause of mortality following hip fractures in older adults is pneumonia and respiratory failure (Groff et al., 2020; Sheikh et al., 2017). Postoperative pulmonary complications (PPCs) are generally defined as respiratory dysfunctions that occur within five to seven days postoperatively and vary in severity (Ball et al., 2016; Miskovic et al., 2017). Common pathologies of PPCs include pneumonia, respiratory failure, acute respiratory distress syndrome (ARDS), pneumothorax, pleural effusion, bronchospasm, aspiration pneumonitis, and atelectasis (Canet et al., 2010; Fernandez-Bustamante et al., 2017; LAS VEGAS Investigators, 2017). PPCs are the second most common surgical complication (Dimick et al., 2004; Healey et al., 2002) and are associated with high mortality, as well as increased intensive care unit admissions and hospital length of stay (Fernandez-Bustamante et al., 2017). Severe PPCs can increase the cost of hospitalization by $35,000 or more (Fleisher et al., 2014; Ruscic et al., 2017; Shander et al., 2011) and reduce the overall hospital profit margin by 5% (Healey et al., 2016). Impaired cognition is one of the known risk factors that are highly associated with PPCs (Miskovic et al., 2017).

Many studies have evaluated the impact of dementia on surgical outcomes in older patients with hip fractures (Chiu et al., 2018; Forssten et al., 2022; Gao et al., 2023; Ha et al., 2021; Hou et al., 2021), yet the risk factors of dementia and poor surgical outcomes are significantly confounded, and it is difficult to isolate the impact of dementia. Thus, little is known about the true impact of dementia on PPCs among patients who undergo hip fracture surgery. Inverse probability of treatment weighting (IPTW) using propensity scores can be utilized to reduce bias by balancing the distributions of confounders between treatment and control groups (Pan et al., 2015; Pan et al., 2016). Therefore, the purpose of this study was to evaluate the unbiased impact of dementia on PPC incidence and severity among older adults who were 65 years or older following hip fracture surgery using IPTW to reduce the influence of confounders. We hypothesized that the isolated impact of dementia increases the odds of PPC incidence as well as PPC severity. Additionally, we evaluated the impact of dementia on hospital length of stay and postoperative 30-day mortality as secondary outcomes. We hypothesized that dementia increases hospital length of stay and incidence of postoperative 30-day mortality.

METHODS

Study Design and Sample

A retrospective observational cohort study was conducted, leveraging electronic health records (EHRs) of an academic health care system in the southeast United States. Older adults who were at least 65 years old and admitted to the health care system between October 1, 2015 and December 31, 2018 for hip fracture surgery were included. The criteria for exclusion were patients with neuromuscular diseases (e.g., amyotrophic lateral sclerosis, myasthenia gravis, muscular dystrophies), insufficient recovery from neuromuscular blockade postoperatively (i.e., use of neuromuscular reversal agents, neostigmine or sugammadex in a post-anesthesia care unit), oversedation and narcotization as indicated by immediate postoperative administration of reversal agents (e.g., naloxone, flumazenil), cases of malignant hyperthermia, or anaphylaxes, and patients who expired during surgical or anesthesia procedure.

The EHR data used for this study were extracted by professional data analysts, and multiple data assessments and cross-validations were performed to ensure data quality and accuracy. To identify older patients who were admitted for surgical intervention of hip fracture, we used the International Classification of Disease 10th Revision (ICD-10) diagnosis and procedure codes and Current Procedural Terminology codes (Supplementary Materials: Figures S1, S2 & S3).

Hip Fracture and Hip Fracture Surgery—The Agency for Healthcare Research and Quality (AHRQ) defined hip fracture as a cracking or breaking of the proximal femur outside the junction of femoral head and acetabulum within the pelvis (Butler et al., 2008). The hip fracture types that we included in this study were femoral neck fracture, intertrochanteric fracture, and subtrochanteric fracture (Butler et al., 2008). Surgical interventions for hip fractures included in this study were: internal fixation, intramedullary internal fixation, hemiarthroplasty, and total hip arthroplasty. We combined international fixation and intramedullary internal fixation, and they are coded as open reduction internal fixation (ORIF). We excluded external fixations for three reasons: (1) the difference in the physiological stress caused by these procedures as they are minimally invasive treatments where a fracture is externally stabilized with screws and rods and are performed under light sedation and local anesthesia (Gani et al., 2009; Hadeed et al., 2020); (2) the indication for these procedures are nonunion, malunion, and/or traction to aid a surgical procedure; and (3) many of these cases are performed outside of the operating room (Hadeed et al., 2020).

Predictor

A diagnosis of dementia was the predictor variable of this study. Dementia diagnosis was identified by the ICD-10 diagnosis codes (Figure S4). Dementia results from conditions that progresses slowly over many years, and diagnosis is often until after a hospitalization or emergency department visit (Amjad et al., 2018; Amjad et al., 2022). To minimize the risk of under-estimating the effects of dementia, we extended the date of diagnosis to 180 days beyond the discharge of the hospital.

Outcomes

Primary Outcome—This study used the recommended consensus definition of PPCs by Abbot et al. (2018), and we modified the definition to make it applicable to an observational study using EHRs. The PPC definition by Abbot et al. is composed of two properties: mechanism and severity. Mechanism refers to diagnosis of the pathophysiologic process, and severity is rated by the level of postoperative requirement for supplemental oxygen and ventilatory support (Abbot et al., 2018).

PPC Diagnosis.: ARDS, pneumonia (including aspiration pneumonia), respiratory failure, and atelectasis were recognized as PPCs in this study. We used ICD-10 diagnosis codes at discharge to identify patients who had a PPC (Figure S5).

PPC Severity.: The severity of the complication was categorized into three levels: (1) without supplemental oxygen; (2) supplemental oxygen requirement with the fraction of inspired oxygen (F_IO_2) < 60% longer than 24 hours following the index surgery; and (3) supplemental oxygen requirement with $F_IO_2 \geq 60\%$, high flow oxygen via nasal cannula or noninvasive or invasive mechanical ventilatory support. These data were collected from flowsheets documented by nurses and respiratory therapists.

Secondary Outcomes—We explored the impact of dementia on 30-day mortality and hospital length of stay as secondary outcomes. Thirty-day mortality was defined as death within 30 days following the hip fracture surgery, and hospital length of stay was defined as the number of days the patient was in the hospital between admission and discharge.

Covariates

Risks for PPC include older age, coexisting multiple chronic illnesses (e.g., chronic obstructive pulmonary disease, cancer, congestive heart failure), low preoperative oxygen saturation, preoperative anemia, hypoalbuminemia, and blood transfusions (Canet et al., 2010; Fernandez-Bustamante et al., 2017; Guldner et al., 2015; LAS VEGAS Investigators, 2017; Miskovic et al., 2017; Sabate et al., 2014). Modifiable factors that are known to increase the risk for dementia are old age and female sex; modifiable risk factors include: smoking, alcohol use, vascular disease, diabetes, obesity, living alone, and lower level of education (Larson, 2019; Launer et al., 1999; Liang et al., 2020). In this study, we included age, biological sex, marital status, race and ethnicity, admission source (i.e., home, skilled nursing facility, or other facilities), and insurance payor (i.e., Medicare or other) as the controlled patient demographic characteristics. Discharge disposition (i.e., home or non-home) was included as a candidate covariate for hospital length of stay; patients who are discharged to non-home locations tend to have longer hospital length of stay (Dang et al., 2022). To control for perioperative health status, we included body mass index (BMI), Charlson Comorbidity Index (CCI), preoperative serum hemoglobin level, preoperative serum albumin measurement, preoperative oxygen saturation (SpO_2), preoperative respiratory condition (i.e., category 1 = no supplemental oxygen; category 2

= use of supplemental oxygen with $FiO_2 < 60\%$ longer than 24 hours postoperatively; category 3 = use of supplemental oxygen with $FiO_2 \geq 60\%$, or high flow oxygen via nasal cannula, or both; category 4 = use of noninvasive ventilatory support or invasive ventilatory support), American Society of Anesthesiologist (ASA) physical status, and admission to intensive care unit (ICU) during hospitalization. The CCI was used as a surrogate measure to quantitatively represent patients' overall health status. The CCI score sums the presence of 22 diseases, weighted on a scale of 1 to 6, based on each disease risk for 10-year mortality or resource use (Charlson et al., 1994). Diseases were identified by the ICD-10 codes (Figure S5). Scores of 0 indicated no comorbid disease, and among the patients who have had hip fracture surgery, a CCI score ≥ 4 predicted 3.1–8.5 times higher risk of mortality when compared to a CCI score of 2–3 (Miettinen et al., 2023).

The other covariates related to surgery and anesthesia included mode of anesthesia (i.e., general or regional), type of surgical procedure (i.e., total hip arthroplasty, hemiarthroplasty, or ORIF), emergency surgical status, time-to-surgery (in hours), duration of surgery (in minutes), and perioperative blood transfusions (Canet et al., 2010; Fernandez-Bustamante et al., 2017; Miskovic et al., 2017; Sabate et al., 2014). Different types of hip fracture surgery carry different degrees of risks and complications, because of variability in physiological impact of each surgical approach (Bhandari et al., 2019; Hopley, Stengel et al., 2010; Jawad et al., 2019). For example, total hip arthroplasty replaces not only the femoral head but also the acetabulum, as compared with hemiarthroplasty, which only replaces the femoral head (Butler et al., 2008). Although total hip arthroplasty is associated with a lower mortality rate than hemiarthroplasty, total hip arthroplasty is the more invasive surgical operation (Jawad et al., 2019). In addition, we constructed a variable to represent time-to-surgery (i.e., the number of hours between admission and surgery) because the timing of surgical intervention is associated with postoperative morbidity and mortality (Seong et al., 2020).

Analysis Plan

Data Preparations—Descriptive statistics were first performed for patient demographic characteristics. All variables were assessed for normality and rate of missingness. We identified that 277 patients had missing data on the outcome variables (i.e., PPC diagnosis and severity). Sensitivity analysis was conducted to examine differences in patient demographic characteristics between patients with and without the missing outcomes; and the results showed that only age, race, and payor type were statistically significant ($p < .05$) but the effect sizes for all the demographic characteristics were small (Cohen's $d < 0.20$; Cramer's $V < 0.10$) (Table S1). Thus, we decided to exclude those 277 patients with missing outcomes rather than performing imputation. After applying the study eligibility criteria, 875 patients remained (Figure 1). Of the 875 patients, 289 patients (33.0%) had a diagnosis of dementia.

Five covariates (BMI, preoperative serum hemoglobin level, preoperative SpO2, ASA physical status, and emergency surgery status) had missing data (0.2 % to 21.4 %). They were evaluated for the missing randomness using Little's missing completely at random (MCAR) test (1988) using the missing value analysis model of IBM SPSS 26.0. Result indicated that the missing data were MCAR (chi-square = 99.56, $p = 0.15$). We opted to perform the expectation-maximization algorithm to impute the missing values for the five covariates to preserve sample size.

To obtain unbiased estimates of the impact of dementia diagnosis on the incidence and severity of PPCs, we employed IPTW using propensity scores (Pan et al., 2015; Pan et al., 2016) to balance baseline characteristics between patients with and without dementia in order to minimize the impact of the confounders (i.e., baseline patient characteristics) on dementia status (Figure 2.A). IPTW was calculated with logistic regression of dementia status on the confounders using SAS 9.4. After IPTW was calculated, weighted regression analysis was performed to evaluate the isolated impact of dementia on the incidence and severity of PPCs with adjusting the confounders as covariates (Figure 2.B). Figure 2.C illustrates the distributions of the probability of having a dementia diagnosis before and after IPTW. Table 1 presents descriptive statistics of the baseline characteristics of the patients with and without a diagnosis of dementia. Additionally, Table 1 includes the descriptive statistics before (unweighted) and after IPTW (weighted).

Outcome Analyses—PPC diagnosis, a binary outcome, was evaluated by weighted logistic regression with forced inclusion of the predictor (i.e., dementia). PPC severity was a multinomial outcome, and weighted multinomial logistic regression with forced inclusion of dementia was performed to evaluate the effect of dementia on PPC severity. In both of the regression analyses, a backward selection method with forced inclusion of dementia was performed to select significant covariates for each outcome; covariates were kept in the model if p-values ≤ 0.10. The secondary outcomes—hospital length of stay and postoperative 30-day mortality—were evaluated by weighted multiple regression and logistic regression, respectively. Logistic regression was chosen for 30-day mortality rather than Cox regression because the duration of time to event was short (Annesi et al., 1989). The significance level was set at $p = 0.05$. All main analyses were performed using SAS 9.4., specifically PROC SURVEYLIGISTIC and PROC SURVEYREG with the IPTW.

Ethical Considerations

The Institutional Review Board declared the study exempt (protocol number Pro0010528), as it was a retrospective observational cohort study using existing EHR data. The data were stored, managed, and analyzed in the institution’s highly protected virtual network space to ensure data safety and security.

RESULTS

Sample Characteristics

Most of the study cohort was female (72.2%) and White (83.8%) with an average age of 82.04 (± 8.65) years. Approximately three-quarters of patients were admitted from home, but only about 10 % of them were discharged home. The majority of the patients were categorized as ASA physical status 3 (65.3%) with a CCI score of 3.07 ± 2.85. More than half of the patients underwent ORIF and only 7.5% had total hip arthroplasty. The most common type of anesthesia was regional anesthesia (72.0%). The overall incidence of PPCs was 18.2% with the highest frequency had a severity level of 1 (n = 422; 48.2%). The average hospital length of stay was 6.30 ± 4.33 days, and the postoperative 30-day mortality rate was 4.5% (Table S2).

Sample Balance with IPTW

Prior to applying IPTW, patients with and without dementia differed significantly on the following characteristics: age, BMI, race, ASA physical status, preoperative serum hemoglobin level, preoperative albumin measurement, marital status, tobacco use, alcohol use, admission source, duration of anesthesia, surgery type, payor type, and discharge disposition (Table 1). Compared to patients without dementia, patients with dementia were more likely to be older ($p < 0.0001$), have lower BMI ($p = 0.006$), be non-white ($p = 0.0005$), have lower preoperative hemoglobin level ($p = 0.0006$), have preoperative albumin measurement ($p = 0.04$), be unmarried ($p < 0.0001$), have no history of smoking ($p < 0.0001$) or alcohol use ($p < 0.0001$), be admitted from a skilled nursing facility ($p < 0.0001$), have a shorter duration of anesthesia ($p = 0.002$), not have total hip arthroplasty ($p < 0.0001$), and be discharged to a location other than their home ($p < 0.0001$). After IPTW was applied, patients with and without dementia were completely balanced without any statistically significant different characteristics (Table 1). Figure 2.C displays side-by-side histograms for the probability of having dementia. Table 2 summarizes the results of weighted regression analyses of the outcomes with IPTW after adjusting for covariates.

Primary Outcome

After controlling for the selected covariates in logistic regression, dementia did not have a statistically significant impact on PPC diagnosis ($p = 0.78$; odds ratio [OR] = 1.07; 95% confidence interval [C.I.] = 0.68, 1.68) (Table S3). Likewise, PPC severity was not statistically significantly impacted by a dementia diagnosis. Multinomial logistic regression was conducted to evaluate PPC severity (Table S4) with the reference group set at the level 1 severity (i.e., without supplemental oxygen). When compared to PPC severity level 1, level 2 had $b = -0.10$ with $p = 0.30$ (OR = 0.81; 95% C.I. = 0.55,1.20), and level 3 had $b = -0.13$ with $p = 0.053$ (OR = 0.77; 95% C.I. = 0.33, 1.76).

Secondary Outcomes

A diagnosis of dementia had a statistically significant impact on hospital length of stay (Table S5). Hospital length of stay increased by 1.37 days when patients had a diagnosis of dementia ($b = 1.37$; $p = 0.028$; 95% C.I. = 0.15, 2.60). The model explained 58.6% of the variance for hospital length of stay ($R^2 = 0.586$). Dementia diagnosis was found not to be a significant factor for postoperative 30-day mortality ($b = 0.034$; $p = 0.86$; OR = 1.07 [0.50–2.28]) (Table S6).

DISCUSSION

With the use of IPTW, our study evaluated the isolated impact of dementia on PPC diagnosis and severity, and on secondary outcomes of hospital length of stay and postoperative 30-day mortality. Our hypotheses regarding PPC diagnosis and severity, as well as postoperative 30-day mortality were not supported. Dementia, after controlling for multiple confounding variables and covariates, did not have a significant impact on PPCs or postoperative 30-day mortality. However, dementia did have an isolated impact on hospital length of stay, which was extended by 1.37 days in patients with dementia.

Hip fractures in older adults are associated with high morbidity and mortality (Groff et al., 2020; Sanz-Reig et al., 2017), and the clinical course can be further complicated by preexisting dementia. Dementia and PPCs are significantly confounded, and many of the risk factors of dementia are also those of PPCs. Patients who are at high risk for PPCs tend to be older, have coexisting multiple chronic illnesses (e.g., cardiovascular disease, diabetes), be obese, have a history of smoking and/or alcohol use, and have cognitive impairment (Canet et al., 2010; Fernandez-Bustamante et al., 2017; Guldner et al., 2015; LAS VEGAS Investigators, 2017; Miskovic et al., 2017; Sabate et al., 2014). These characteristics are also known as risk factors of dementia (Larson, 2019). Prior studies identified dementia as a significant risk factor for developing PPCs (Chen et al., 2020; Hu et al., 2012; Kim et al., 2013). Compared to patients without dementia, patients with dementia had significantly higher rates of pneumonia (RR = 1.66; $p < 0.0001$) (Bail et al., 2013). Similarly, Tsuda et al. (2015) reported that dementia as a significant risk for postoperative complications including PPCs occurred most frequently in older patients (≥ 70 years) following hip fracture surgeries (Tsuda et al., 2015). Patients with dementia had 1.5-fold higher odds of developing PPCs (OR = 1.49; $p < 0.0001$) (Tsuda et al., 2015). These prior studies used traditional regression analyses. In contrast, we found no statistically significant impact of dementia on PPC incidence and severity as well as postoperative 30-day mortality. We used IPTW to balance distributions of confounders between patients with and without dementia to evaluate the isolated impact of dementia on PPCs incidence and severity. The use of propensity score methods such as IPTW is a superior approach to evaluating causal effects using observational studies (Amoah et al., 2020). We included all available variables from pre-, intra-, and postoperative phases to account for confounding between groups, although we recognize that there may still be residual confounding from variables that were not measured or observed.

Our study did not find a significant difference in the rate of postoperative 30-day mortality between patients with and without dementia. The postoperative mortality rate following hip fracture surgeries increases as time goes by (Bai et al., 2018; Hou et al., 2021). Indeed, a study conducted in the same institution as this study found a statistical significance in both six months mortality (Hazard Ratio =1.69; $p = 0.003$) and one-year mortality (Hazard Ratio = 1.78; $p < 0.0001$) in older adults with dementia following hip fracture surgery (Xue et al., 2022). Thus, one of the plausible explanations might be that the postoperative 30 days were not long enough to see the effect of dementia. Conflicting findings on the impact of dementia on postoperative 30-day mortality have been observed (Chiu et al., 2018; Khan et al., 2013; Kim et al., 2013; Sheikh et al., 2017), and these studies used traditional regression analyses. It is reasonable to assume that our study yielded less biased results as we used IPTW.

A systematic review of 60 studies (Möllers et al., 2019) revealed patients with dementia tend to stay in the hospital longer than patients without dementia regardless of the reason for hospitalization, though seven studies particularly about hip fractured patients had inconsistent findings. In our study, the average hospital length of stay in the overall study population was 6.30 days, and the stay was extended by 1.37 days for patients with dementia. Similarly, Ahluwalia et al. (2023) found that demented patients had a longer hospital length of stay than non-demented patients (7 days vs. 6 days; $p<0.0001$) following total hip arthroplasty for femoral neck fracture (Ahluwalia et al., 2023). Patients with dementia are at risk for numerous postoperative complications leading to longer hospital length of stay, such as PPCs, delirium, urinary tract infection, acute renal failure, postoperative anemia, and pressure ulcer (Bail et al., 2013; Zachwieja et al., 2019). Postoperative delirium is common and is observed in up to 87% depending on patient characteristics and the type of surgery (Whitlock et al., 2011). A meta-analysis that included six studies demonstrated that dementia increases the risk for postoperative delirium by 3.6-fold (OR = 3.59; $p < 0.00001$) (Mosk et al., 2017). Given these facts, one of the plausible explanations for longer lengths of stay in patients with dementia could be postoperative complications such as delirium. Mosk et al. (2017) found that patients with dementia had a significantly higher incidence of delirium than patients without dementia, and delirium was associated with prolonged hospital length of stay. Another explanation for the longer stay could be logistical issues such as identifying an institution to which a patient could be discharged. In our study, 67.1 % ($n = 194$ of 289) of patients with dementia were admitted from home, yet only 5.2% ($n = 15$) of them were discharged home. Indeed, in another study, patients with dementia had 2.11-fold higher odds of being discharged to a location other than their home, such as another hospital or skilled nursing facility (Xue et al., 2022). Many older patients following a hip fracture surgery endure multiple transitions of care (e.g., hospital to long-term care facility). During these care transitions, increased stress, frustration, and confusion are frequently experienced due to ineffective communication and lack of coordination (Brooks et al., 2021). Given our study indicating prolonged hospitalization for demented patients, it is reasonable to imagine that these avoidable obstacles can be even more challenging for them and their caregivers. There are significant opportunities to improve nursing care by creating an environment where patients can focus on healing.

Study Limitations

We acknowledge that our study has several limitations. Amjad et al. (2018) identified that approximately 60% of adults aged 65 or older were either undiagnosed or unaware of the dementia diagnosis. Signs and symptoms of dementia often are not recognized and diagnosed until an encounter with health care providers such as during a hospitalization or a visit to an emergency department; thus, we extended the date of dementia diagnosis for 180 days beyond hospital discharge after hip fracture surgery to capture such cases. We recognize there is a significant possibility of underestimating the number of patients with dementia because underdiagnosis and unawareness of dementia are prevalent; however, it is also possible that some patients with prolonged delirium were misclassified as having dementia.

Many of the study limitations are secondary to the nature of retrospective observational study using EHRs. Though we applied IPTW using the propensity score to reduce biases in this retrospective observational study, the potential remains for a confounded relationship between exposure and outcome (Shadish et al., 2002). Therefore, caution should be taken when interpreting the results not to draw a causal relationship. The original purpose of EHRs is not for research; thus, there were issues around the availability of data needed for a study. For example, it would have been ideal to have an indicator for dementia severity from a brief objective measure of cognition, but such data were not available. Additionally, PPC diagnosis and CCI score were identified by using the ICD-10 diagnosis codes. The ICD-10 codes are entered in EHRs for billing purposes; thus, we recognize the potential for inaccuracy and underestimation of those variables. Lastly, this was a single-center study with limited generalizability because the sample may not adequately reflect variability among hip fracture patients nationally (Raman et al., 2018).

CONCLUSIONS

We found that dementia did not have a significant impact on PPC incidence and severity after controlling for potential confounders, and this differs from the findings of prior studies. A multicenter study with a larger sample size should be conducted to verify the results of this study. Future studies should examine whether dementia severity influences the incidence and severity of PPCs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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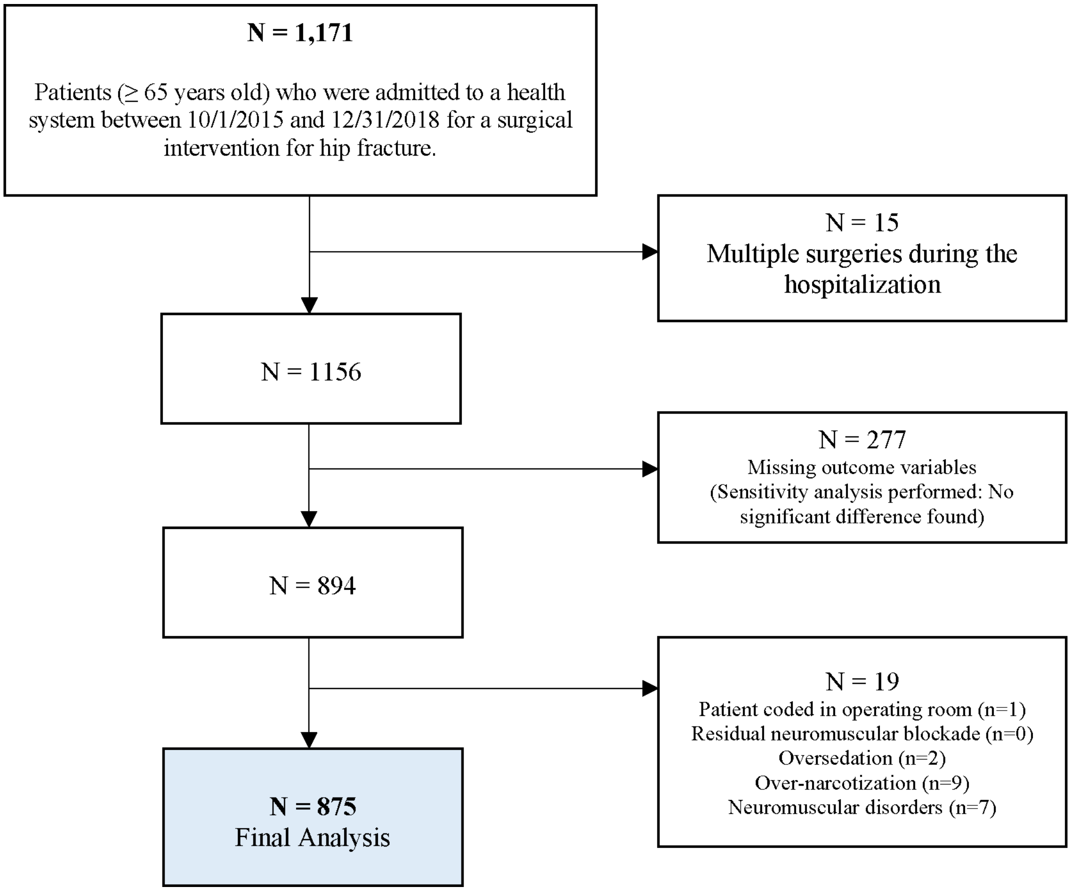

Figure 1.
Consort Diagram: Defining Study Cohort

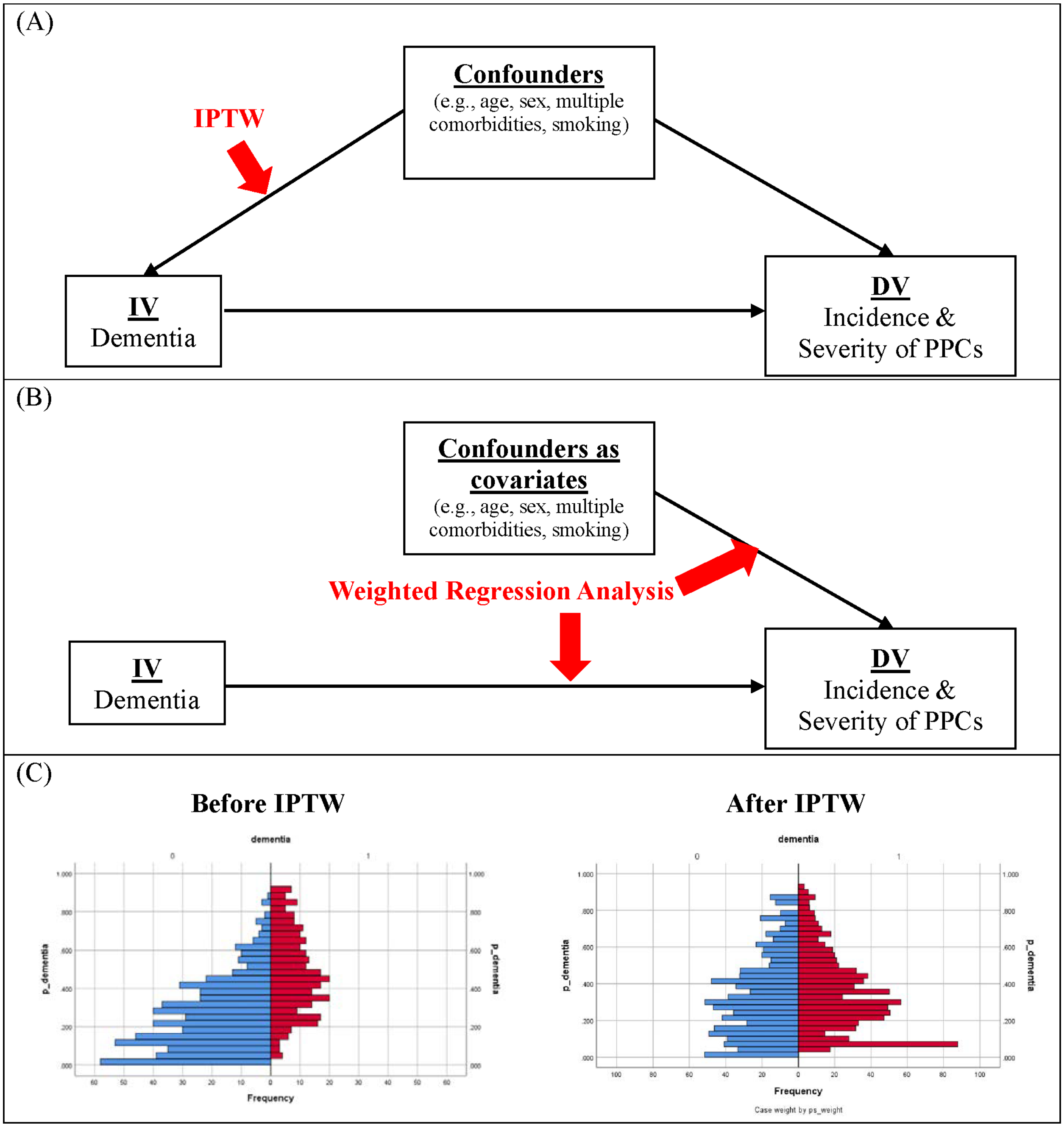

Figure 2. Analytical Framework

(A) IPTW is applied to minimize the impact of confounders on dementia status (IV); (B) With the removal of the arrow between the confounders and dementia (DV) after applying IPTW, weighted regression analysis is performed to evaluate the isolated impact of dementia (IV) on incidence and severity of PPCs (DV), adjusting for the confounders as covariates; (C) Side-by-side histograms for probability of having a dementia diagnosis before and after IPTW application (0 = without dementia; 1 = with dementia).

Note. IV = independent variable; DV = dependent variable; PPCs = postoperative pulmonary complications; IPTW = inverse probability of treatment weighting.

Table 1.

Patient Characteristics Unweighted and Weighted (N = 875)

	Unweighted				Weighted		
	Overall (N = 875)	**With Dementia (n = 289)**	**Without Dementia (n = 586)**		**With Dementia (n = 824.89)**	**Without Dementia (n = 877.69)**	
Numerical Variables	**Mean (SD)/ Min-Max**	**Mean (SD)/ Min- Max**	**Mean (SD)/ Min- Max**	**T-test p-value**	**Mean (SEM) [95% CI]**	**Mean (SEM) [95% CI]**	**T-test p-value**
Age (year)*	82.04 (8.65)/ 65–104	85.36 (7.36)/ 65–104	80.41 (8.77)/ 65–103	<.0001	83.18 (0.75) [81.71, 84.65]	82.17 (0.40) [81.38–82.96]	.23
BMI	24.65 (5.54)/ 14.20–60.20	23.93 (5.33)/ 14.20–51.80	25.01 (5.62)/ 14.20–60.20	.0056	24.68 (0.57) [23.55, 25.80]	24.59 (0.25) [24.10–25.08]	.89
CCI total score*	3.07 (2.85)/ 0–19	3.14 (2.48)/ 0–13	3.04 (3.01)/ 0–19	.59	3.47 (0.22) [3.04, 3.90]	3.11 (0.15) [2.83–3.40]	.18
Preop Hgb (g/dl)	11.30 (1.82)/ 6.60–17.00	11.01 (1.77)/ 6.60–15.50	11.45 (1.83)/ 7.00–17.00	.0006	11.09 (0.15) [10.80, 11.38]	11.28 (0.082) [11.12–11.44]	.25
Preop SpO2 (%)	96.34 (2.56)/ 80–100	96.24 (2.65)/ 84–100	96.39 (2.52)/ 80–100	.43	96.29 (0.25) [95.80, 96.78]	96.34 (0.11) [96.13–96.55]	.85
Time to surgery (hour)	29.57 (34.17)/ 0.72–557.62	30.67 (40.65)/ 0.78–557.62	29.03 (30.56)/ 0.72–417.42	.55	33.27 (4.14) [25.13, 41.41]	29.92 (1.53) [26.93–32.92]	.45
Duration of anesthesia (min)	159.50 (50.75)/ 44–369	152.16 (46.99)/ 44–353	163.12 (52.16)/ 59–369	.0019	154.24 (3.29) [147.77, 160.71]	158.61 (2.41) [153.86–163.35]	.29
Categorical Variables	**N (%)**	**N (%)**	**N (%)**	**Chisqp-value**	**N (%)**	**N (%)**	***Chisqp-value**
Biological sex: female	632 (72.23%)	213 (73.70%)	419 (71.50%)	.49	631.28 (76.53%)	643.95 (73.37%)	.38
Marital status: married	337 (38.51%)	81 (26.30%)	256 (43.69%)	<.0001	296.99 (36.00%)	331.94 (37.82%)	.68
Race (White)	733 (83.77%)	224 (77.51%)	509 (86.86%)	.0005	680.49 (82.50%)	738.28 (84.12%)	.62
Payor (Medicare)	707 (80.80%)	247 (85.47%)	460 (78.50%)	.012	677.48 (82.13%)	713.71 (81.32%)	.83
Admission source				<.0001			.94
Home	661 (75.54%)	194 (67.13%)	467 (79.69%)		620.34 (75.20%)	668.08 (76.12%)	
Skilled nursing facility	78 (8.91%)	56 (19.38%)	22 (3.75%)		77.30 (9.37%)	75.31 (8.58%)	
Other	136 (15.54%)	39 (13.49%)	97 (16.55%)		127.25 (15.43%)	134.30 (15.30%)	
Tobacco use	438 (50.06%)	117 (40.48%)	321 (54.78%)	<.0001	391.79 (47.50%)	438.27 (49.93%)	.59
Alcohol use	211 (24.11%)	45 (15.57%)	166 (28.33%)	<.0001	155.74 (18.88%)	208.07 (23.71%)	.19
Diabetes	285 (32.57%)	89 (30.80%)	196 (33.45%)	.43	295.72 (35.85%)	292.12 (33.28%)	.56
Cardiovascular diseases	299 (34.17%)	89 (30.80%)	210 (35.84%)	.14	348.60 (42.26%)	308.75 (35.18%)	.11

	Unweighted				Weighted		
	Overall (N = 875)	With Dementia (n = 289)	Without Dementia (n = 586)		With Dementia (n = 824.89)	Without Dementia (n = 877.69)	
Numerical Variables	**Mean (SD)/ Min-Max**	**Mean (SD)/ Min- Max**	**Mean (SD)/ Min- Max**	**T-test p-value**	**Mean (SEM) [95% CI]**	**Mean (SEM) [95% CI]**	**T-test p-value**
Preop respiratory status				.42			.64
Category 1	536 (61.26%)	185 (64.01%)	351 (59.90%)		468.05 (56.74%)	537.68 (61.26%)	
Category 2	298 (34.06%)	93 (32.18%)	205 (34.98%)		312.57 (37.89%)	300.30 (34.21%)	
Category 3 & 4	41 (4.69%)	11 (3.81%)	30 (5.12%)		44.27 (5.37%)	39.71 (4.52%)	
Preop Albumin measured	438 (50.06%)	159 (55.02%)	279 (47.61%)	.039	403.37 (48.90%)	423.02 (48.20%)	.87
ICU stay	59 (6.74%)	21 (7.27%)	38 (6.48%)	.67	79.24 (9.61%)	63.46 (7.23%)	.41
ASA Physical Status				.0001			.70
ASA 1 or 2	121 (13.83%)	23 (7.96%)	98 (16.72%)		90.04 (10.92%)	118.41 (13.49%)	
ASA 3	571 (65.26%)	189 (65.40%)	382 (65.19%)		550.65 (66.75%)	566.61 (64.56%)	
ASA 4	183 (20.91%)	77 (26.64%)	106 (18.09%)		184.20 (22.33%)	192.67 (21.95%)	
Emergency surgery	129 (14.74%)	42 (14.53%)	87 (14.85%)	.90	139.18 (16.87%)	129.56 (14.76%)	.53
General anesthesia	245 (28.00%)	76 (26.30%)	169 (28.84%)	.43	231.46 (28.06%)	245.48 (27.97%)	.98
Surgery type				<.0001			.70
ORIF	494 (56.46%)	183 (63.32%)	311 (53.07%)		490.31 (59.44%)	504.71 (57.50%)	
Hemiarthroplasty	315 (36.00%)	103 (35.64%)	212 (36.18%)		292.74 (35.49%)	306.82 (34.96%)	
Total hip arthroplasty	66 (7.54%)	3 (1.04%)	63 (10.75%)		41.83 (5.07%)	66.17 (7.54%)	
Preop blood transfusion	68 (7.77%)	23 (7.96%)	45 (7.68%)	.88	106.30 (12.89%)	73.43 (8.37%)	.16
Intraop blood transfusion	48 (5.49%)	18 (6.23%)	30 (5.12%)	.50	64.00 (7.76%)	47.99 (5.47%)	.36
Postop blood transfusion	267 (30.51%)	95 (32.87%)	172 (29.35%)	.29	267.84 (32.47%)	270.46 (30.81%)	.69
Discharge Disposition				<.0001			.18
Home	95 (10.86%)	15 (5.19%)	80 (13.65%)		55.76 (6.76%)	94.86 (10.81%)	
Non-Home	780 (89.14%)	274 (94.81%)	506 (86.35%)		769.13 (93.24%)	782.83 (89.19%)	

[*] Chisq = Rao-Scott Likelihood Chi-square test; BMI = body mass index; CCI = Charlson comorbidity index; SpO_2 = oxygen saturation; ICU = intensive care unit; Preoperative Respiratory Status (Category 1 = without supplemental oxygen, Category 2 = use of supplemental oxygen with $FiO_2 < 60\%$ longer than 24 hours postoperatively, Category 3 = use of supplemental oxygen with $FiO_2 \geq 60\%$, or high flow oxygen via nasal cannula, or both, Category 4 = use of NIMV or IMV); ASA = American Society of Anesthesiologists (ASA1 = normal healthy patient, ASA2 = mild systemic disease, ASA3= severe systemic disease, ASA4 = severe systemic disease that is constant threat to life, ASA5 = not expected to survive without the operation); ORIF = open reduction and internal fixation.

Table 2.

Results of Outcome Analyses: Adjusted for Covariates

PPC Diagnosis	**Parameter Estimate (SE)**	**p-value**	**OR [95% C.I.]**
Intercept	8.73 (4.13)	0.035	—
With dementia	0.032 (0.12)	0.78	1.067 [0.68, 1.68]
	Level 1 vs. Level 2		
PPC Severity	**Parameter Estimate (SE)**	**p-value**	**OR [95% C.I.]**
Intercept	14.81 (4.25)	.0005	—
With dementia	−0.10 (0.099)	.30	0.81 [0.55, 1.20]
	Level 1 vs. Level 3		
Intercept	22.86 (7.28)	.0018	—
With dementia	−0.13 (0.21)	.053	0.77 [0.33, 1.76]
Hospital Length of Stay	**Estimate (SE)**	**p-value**	**[95% C.I.]**
Intercept	4.41 (0.77)	<.0001	[2.90, 5.93]
With dementia	1.37 (0.62)	.028	[0.15, 2.60]
Postoperative 30-Day Mortality	**Parameter Estimate (SE)**	**p-value**	**OR [95% C.I.]**
Intercept	3.53 (1.43)	.014	—
With dementia	0.034 (0.19)	.86	1.07 [0.50, 2.28]

Note. PPC = postoperative pulmonary complications; SE = standard error; OR = odds ratio; C.I. = confidence interval.