Title

Trends and Impact of Chronic Obstructive Pulmonary Disease on Patients Undergoing Shoulder Arthroplasty

Author
Lin, Charles Chun-Ting

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Trends and Impact of Chronic Obstructive Pulmonary Disease on Patients Undergoing Shoulder Arthroplasty

THESIS

submitted in partial satisfaction of the requirements

for the degree of

MASTER OF SCIENCE

in Biomedical and Translational Science

by

Charles Chun-Ting Lin

Thesis Committee:
Professor Thay Q. Lee, Chair
Doctor Ronald A. Navarro
Professor Sheldon Greenfield

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LIST OF ABBREVIATIONS

ACL - anterior cruciate ligament

AHRQ - Agency for Healthcare Research and Quality

aTSA - anatomic total shoulder arthroplasty

CCR - cost-to-charge ratios

COPD - chronic obstructive pulmonary disease

CPAP - positive airway pressure

DALYs - disability-adjusted life years

FEV1 - Forced expiratory volume in 1 second

FVC - Forced vital capacity

HA - hemi-arthroplasty

HCUP - Healthcare Costs and Utilization Project

HMO - health maintenance organization

ICD-10 - International Classification of Disease 10th Revision

ICD-9-CM - International Classification of Disease 9th Revision, Clinical Modification

NIS - National Inpatient Sample

rTSA - reverse total shoulder arthroplasty

THA - total hip arthroplasty

TJA - total joint arthroplasty

TKA - total knee arthroplasty

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ABSTRACT OF THE THESIS

Trends and Impact of Chronic Obstructive Pulmonary Disease

on Patients Undergoing Shoulder Arthroplasty

By

Charles Lin

Master of Science in Biomedical and Translational Science

University of California, Irvine, 2018

Professor Thay Q. Lee, Chair

Background:

As the incidence of shoulder arthroplasty continues to increase, the number of patients with chronic obstructive pulmonary disease (COPD) undergoing shoulder arthroplasty also increases. COPD has been shown to be a significant risk factor in general surgery, total hip arthroplasty and total knee arthroplasty, where it is associated with an increase in complication rates and mortality after surgery.

Methods:

This was a retrospective administrative database study using the National Inpatient Sample (NIS) from 2001 to 2014. Patients undergoing shoulder arthroplasty were identified using ICD-9-CM procedural codes and split into two groups: patients with COPD and without COPD. Trends of patients undergoing shoulder arthroplasty across the years were determined. Univariate statistical analysis was used to compare demographics, comorbidity and complication rates. Multivariate regression was used to determine the independent risk that COPD contributes to complications. Inpatient cost and length of stay were also compared between groups.

Results:

The incidence of shoulder arthroplasty has increased by 294% between 2001-2014. The number of patients with COPD has also increased, with 324% growth. COPD patients had significantly higher rates of comorbidities, especially congestive heart failure (COPD: 10.42% vs. non-COPD: 3.41%; $p < .001$) and depression (COPD: 16.75% vs. non-COPD: 11.63%; $p < .001$). They also had higher rates of post-operative complications, particularly respiratory complications (COPD: 5.70% vs. non-COPD: 1.25%; adjusted OR = 3.51; $p < .001$), overall complications (COPD: 10.48% vs. 4.37%; adjusted OR = 1.98; $p < .001$) and higher risk of mortality (COPD: 0.31% vs. non-COPD: 0.13%.; adjusted OR = 1.59; $p < .001$).

Discussion:

Shoulder arthroplasty in COPD patients is continuing to grow rapidly. COPD patients tend to have greater comorbidity burdens, higher rates of post-operative complications (especially respiratory complications) and increased mortality. Improved pre-surgical optimization and increased attention to post-operative management is necessary to improve outcomes of patients with COPD undergoing shoulder arthroplasty.

INTRODUCTION

The incidence of shoulder arthroplasty continues to grow rapidly. (1–3) As the population continues to age and patient comorbidity burdens continue to grow, the absolute number of patients with serious comorbidities such as chronic obstructive pulmonary disease (COPD) will also continue to increase. (4) Therefore, a better understanding of the trends of COPD in shoulder arthroplasty and the impact of COPD on patients undergoing shoulder arthroplasty will help to inform clinical decision making.

COPD is a chronic inflammatory disease characterized by obstructed airflow through the respiratory system and is a significant contributor of morbidity and mortality in the United States. (5,6) COPD has been established as a surgical risk factor in general surgery (7–10) and in other areas of orthopedics such as total hip arthroplasty (THA) (11,12) and total knee arthroplasty (TKA) (13,14). In those previous studies, COPD has been shown to be associated with increased post-surgical complication rates and increased mortality. However, its impact on post-shoulder arthroplasty outcomes has not yet been comprehensively assessed. In this thesis, the following questions will be addressed:

Question 1: What are the trends of patients with COPD undergoing shoulder arthroplasty?

Hypothesis 1: Rates of shoulder arthroplasty and the proportion of patients with COPD undergoing shoulder arthroplasty are increasing.

Question 2: What are the inpatient outcomes of patients with COPD undergoing shoulder arthroplasty?

Hypothesis 2: COPD is associated with an increased rate of inpatient complications after shoulder arthroplasty.

Question 3: How does COPD affect costs of care and length of stay after shoulder arthroplasty?

Hypothesis 3: COPD is associated with increased costs of care and increased length of stay after shoulder arthroplasty.

By answering these questions, the results from this study will be able to help inform pre-operative optimization and postoperative management of patients with COPD undergoing shoulder arthroplasty to achieve better outcomes. Furthermore, it will help to inform surgeons on what comorbidities and complications should be focused on and mitigated in patients with COPD undergoing shoulder arthroplasty.

BACKGROUND

Shoulder Arthroplasty

The first shoulder arthroplasty dates back to 1893, when French surgeon Jules-Emile Pean first implanted a platinum-and-rubber prosthesis. (15) Since then, there have been many technological advances in prosthesis materials and design. With these advances, the indications and use cases for shoulder arthroplasty have continued to expand. Currently, there are a variety of indications for shoulder arthroplasty, including: primary osteoarthritis, post-traumatic osteoarthritis, rheumatoid arthritis, severe proximal humerus fractures, cuff tear arthropathy, shoulder girdle tumors and osteonecrosis. (16)

Three main options for shoulder arthroplasty exist: hemi-arthroplasty (HA), anatomic total shoulder arthroplasty (aTSA) and reverse total shoulder arthroplasty (rTSA). (16) These options generally differ in terms of the bony surfaces that are replaced and the level of constraint of the resulting joint. In HA, only the humeral portion of the shoulder joint is replaced with a prosthesis and can be done with either a stemmed humeral component or with just resurfacing of the humeral head. The aTSA usually replaces the humeral head with a stemmed humeral component and resurfaces the glenoid with a polyethylene glenoid component. This prosthesis attempts to restore the native biomechanics of the shoulder joint, but to do so, an intact or reparable rotator cuff is usually necessary. In contrast, the reverse shoulder arthroplasty alters the biomechanics of the shoulder and places a glenosphere onto the glenoid and a socket onto the humeral side. Doing so results in a generally more constrained system but allows the patient to rely more on the deltoid rather than supraspinatus for shoulder abduction. (17)

The shoulder is the third most commonly replaced joint, after hip and knee joints. (18) In recent decades, the incidence of shoulder arthroplasty has continued to rise rapidly. (1–

3,19,20) In the early 1990s, there were fewer than 10,000 shoulder arthroplasties performed. However, by 2008, this number had increased to over 45,000 per year (3) and from 2000 to 2010, the rate of total shoulder arthroplasty increased by four-fold. (20) In 2003, the FDA approved reverse shoulder arthroplasty in the United States, however total shoulder arthroplasty and reverse shoulder arthroplasty were coded together under the ICD-9 code of 81.80. It wasn't until 2011 that rTSA was separated into its own code of 81.88. (2)

In shoulder arthroplasty, there are many contributing factors that could affect postoperative outcomes. It is well accepted that medical comorbidities are significant contributors to post-operative complications, with increasing comorbidity burden being associated greater cost and worse outcomes. (21,22) Hospital volume has also been associated with outcomes in shoulder arthroplasty, with higher volumes associated with better outcomes. (23) Additionally, discharge destination is an independent risk factor for readmission and complications after shoulder arthroplasty. (24)

Chronic Obstructive Pulmonary Disease

Chronic obstructive pulmonary disease (COPD) is the 4th leading cause of chronic-disease related morbidity and mortality in the United States, accounts for 120,000 deaths annually, and is projected to be the 3^{rd} leading cause of death worldwide by 2020. (5,6) In 2002, COPD was the 11th leading cause of disability-adjusted life years (DALYs) lost and was projected to become the 7th leading cause of DALYs lost worldwide in 2030. (25) Furthermore, COPD contributes a significant amount of cost to healthcare spending with the estimated cost of treating a patient with severe COPD at $10,812 per year. (26)

While COPD continues to be a significant contributor of morbidity and mortality in the United States, the overall prevalence of COPD has stabilized since 2009-2011 (27) and the mortality rate has slowly trended down. (28) However, this improvement in COPD prevention and treatment is not uniform across all populations. As the overall numbers of patients with COPD decreases, the proportion and absolute number of women being diagnosed with COPD has continued to increase. The current trend has generally been attributed to a drop in the number of males diagnosed with COPD, likely due to a reduction in population-wide smoking habits. (29,30)

COPD is a chronic inflammatory disease that is characterized by obstructed airflow through the respiratory system. There are two main conditions that fall under the overarching disease classification of COPD: emphysema and chronic bronchitis. Emphysema is characterized by the destruction of the alveolar walls, resulting in increased amounts of lung dead space. This prevents effective gas exchange due to the decreased surface area over which gas exchange can occur. In contrast, chronic bronchitis is due to chronic inflammation of the bronchial tubes. This chronic inflammation results in excessive sputum production, which causes blockage of the airways and causes physiologic changes over time. (6)

Patients with COPD usually present with chronic and progressive dyspnea, chronic cough and/or sputum production. While physical exam and patient history can clue healthcare providers in to the diagnosis of COPD, definitive diagnosis of COPD requires pulmonary testing with spirometry. With spirometry, the criterion for diagnosis of COPD is a post-bronchodilator FEV1/FVC ratio less than 0.7, confirming persistent airflow limitations. (31) COPD patients can present with a wide variety of symptoms and a broad spectrum of severities. To help classify the severity of COPD, patients can either be categorized by (1) the number of exacerbations in the previous 12 months or (2) by the GOLD classification. The GOLD classification was introduced in 2001 and divides COPD into 4 different stages based on FEV_1 in patients with a FEV_1/FVC ratio < 0.70. (6,31)

The pathophysiology of COPD varies with the underlying causes and type of condition. Cigarette smoking is generally the most commonly associated risk factor with COPD, however, there may also be substantial prevalence (3-11%) of COPD among never-smokers. (32) Occupational exposures including organic and inorganic dusts, chemical agents, wood, animal dung, crop residues and burned coal can also be significant risk factors for the development of COPD. (31) Furthermore, genetic factors or diseases such as alpha-1-antitrypsin deficiency may also contribute to the development of COPD. (33)

Goals of treatment for stable COPD are to reduce symptoms and to reduce risks of future events. Reducing symptoms allows for improved exercise tolerance and improved health status whereas reducing exacerbation risk prevents disease progression and reduces mortality. Choices for medical therapy include bronchodilators (beta2-agonists and anticholinergics), corticosteroids and phosphodiesterase-4 inhibitors. In general, inhaled formulations are preferred over oral formulations. (31)

COPD has been well established as an independent surgical risk factor. (7–10) However, surgical risks in COPD patients are often further elevated due to smoking, poor health status, age, obesity and severity of COPD. (9) Post-operatively, patients with COPD are at higher risk of lung infections, atelectasis, increased airflow limitation and acute respiratory failure. (10) The site of surgery is the most important predictor of post-operative pulmonary complications in COPD patients and increases as the surgical site approaches the diaphragm. (34) Due to the higher risk of post-operative complications in this population, there should be close management from the surgeon, pulmonary specialist and primary clinician. Preoperative optimization is therefore extremely important for reducing the risk of complications.

Within orthopedic surgery, COPD has been established as a significant surgical risk factor. (11–14,21,35–37) COPD was found to be a significant independent risk factor in previous studies looking at potential risk factors for complications within 30 days (36) and readmission within 30 days (21) of shoulder arthroscopy. Previous studies have also established that COPD increases complication rates in total joint arthroplasty (TJA), especially with regards to respiratory complications and mortality. (11–14) Additionally, COPD has been associated with an increased rate of needing critical care after TJA. (38)

Database Research

With the rise of "big data", database research studies have become increasingly common in orthopedics. (39–42) There are various databases which vary based on accessibility, data collection methodology and variables collected. Of these databases, the NIS is the most commonly used database in orthopedics, and spine and adult reconstruction substantially lead the rest of the orthopedic subspecialties in the number of database research articles. (40)

As with any research tool, these databases come with strengths and limitations. One of the major strengths of using large databases are the large sample sizes that can be achieved. This gives rise to more accurate population-wide estimates and allows for study of relatively rare conditions or rare outcomes. The ability for databases to answer study questions depends heavily on the limitations of each particular dataset. Therefore, researchers must carefully select an appropriate question for the database they are using. (43) The biggest limitation of database studies is that they are heavily dependent on coding and data entry into the database, as there is no way to go back and verify the accuracy of the data. (44) Furthermore, results may vary depending on the different database used as they capture different populations. (45) Large sample sizes also result in high degrees of power, which allow for statistical detection of small, possibly clinically insignificant findings. (43) Despite these limitations, database research studies are still valuable for providing real-world evidence.

METHODS

Background of the Nationwide Inpatient Sample (NIS) Database

The NIS is a large administrative database that captures a 20% representative sample of all United States hospital encounters. (46) It is a part of the Healthcare Costs and Utilization Project (HCUP) which is managed by the Agency for Healthcare Research and Quality (AHRQ). As the largest collection of administrative, longitudinal healthcare data in the United States, it is designed to be representative of overall healthcare usage, making it ideal for analyzing national estimates and trends over time.

The NIS database is considered an administrative database because it collects the administrative components of a hospital encounter. It is best used for determining trends on national prevalence / incidence and determining associations between diagnosis, procedures and outcomes. (43) The database has been organized and collected on a yearly basis since 1988, with the most current year being the 2015 dataset. For most of the years collected, *International Classification of Disease 9th Revision, Clinical Modification* (ICD-9-CM) codes are used to identify procedures, diagnoses and comorbidities. However, starting with the 3rd quarter of 2015, the NIS started to use *International Classification of Disease 10th Revision* (ICD-10) for coding purposes. Throughout the history of the NIS, it has undergone extensive changes in terms of the types of data collected and the sampling methodology. Over time, different variables have been added or removed from the database, so it is necessary to ensure that the variables of interest are collected over the entire study time period specified.

Design of National Inpatient Sample

The NIS database includes over 7 million inpatient records per year. (47) Due to its expansive nature, the NIS utilizes a stratified methodology for data collection. This results in a weighting methodology that needs to be applied in order to extrapolate the data into a national estimate. Before 2012, the NIS was a sample of hospitals from which all discharges were collected. Beginning with the 2012 dataset, the NIS was changed to a sampling of all discharge records from participating hospitals.

Before the 2012 redesign, the Nationwide Inpatient Sample was a sampling of hospitals based on stratifications defined by 5 hospital elements. These hospital elements were: geographic region (Northeast, Midwest, West and South), control (public, private not-for-profit, and private investor-owned), location (urban or rural), teaching status (teaching or non-teaching) and bed size (small, medium, large). In 2012, the Nationwide Inpatient Sample underwent a significant redesign that affected the sampling methodology. Along with this methodology change, the "Nationwide Inpatient Sample" was renamed the "National Inpatient Sample". This redesign incorporated three major changes: (1) revision of the sampling design to a sample of discharge records from participating hospitals, rather than a sample of hospitals; (2) revision of how hospitals and discharges are defined from the definitions used by the AHA Annual Survey to the definitions and discharges supplied by statewide data organizations; and (3) revisions to enhance confidentiality by removing state and hospital identifiers and aggregating ages over 90 years into a single category. Furthermore, the stratification of the NIS became based on 9 Census Divisions rather than 4 Census Regions, allowing for more geographic detail. (47)

The effect of the redesign was that the estimates generated from the NIS should be approximately twice as precise as the previous sampling methodology. However, due to the redesign, there is a disruption in historical trends which requires reweighting of the years before 2012. The overall impacts of such a change is a slight drop in historical discharge counts, length of stay, charges and mortality. (50) For data after the redesign to be comparable to the data before the redesign, a different set of weights supplied by the HCUP needs to be applied to the years before the change. (47) In order to incorporate the complex sampling design of the NIS, all statistical analysis need to be adjusted utilizing the provided trend weights in order to create national estimates from the provided data.

Limitations of the National Inpatient Sample Database

As an administrative database, the database provides data related to diagnosis codes, procedure codes and costs but it is limited in terms of clinical components of hospital encounters, such as vital signs or laboratory values. (42,43) Furthermore, since the database collects deidentified data on individual hospitalizations, it is impossible to track a single individual through time. Therefore, a key limitation of the NIS is the lack of longitudinal data. (43) Additionally, it only tracks patients in an inpatient setting and does not collect data on ambulatory procedures. (41,42)

Sample Selection

This was a retrospective review of the NIS. In this thesis, the sample years of 2001-2014 were chosen to be collected and analyzed due to availability and cross-year compatibility of sample variables. The NIS collects ICD-9-CM procedure codes that record what procedures patients undergo during their inpatient stays. The ICD-9-CM procedure codes used for shoulder arthroplasty were (2,50): 81.81 for hemiarthroplasty, 81.80 for anatomic total shoulder arthroplasty and 81.88 for reverse total shoulder arthroplasty. All hospitalization entries which underwent shoulder arthroplasty between the years of 2001 to 2014 were included. To encapsulate only the adult population, patients under the age of 18 were excluded from the analysis. COPD was classified using the ICD-9-CM codes 490-492, 496. (12,14) The set of ICD-9-CM codes used are provided in Table 1.

Data Collection and Analysis

A number of other pieces of data were extracted from the NIS dataset for analysis. Demographic information included age, sex, race (white, black, Hispanic, asian or pacific islander, native american, other), hospital size (small, medium, large), hospital region (Northeast, Midwest, South, West) and primary payer type (Medicare, Medicaid, private including HMO, self-pay, no charge, other).

The ICD-9-CM codes for comorbidities were derived from the Elixhauser Comorbidity Index. The Elixhauser Comorbidity Index is a comorbidity index that defines 30 comorbidities using ICD-9-CM codes. (51) Since its introduction, the index has been well validated and has gone through multiple revisions to adjust for changes in ICD coding. (52)

The outcome information that was extracted and analyzed from the NIS dataset included disposition (routine, transfer to short term hospital, other transfer, home health care, against medical advice, died or discharged alive, destination unknown) and in-hospital complications. The complications that were assessed included neurologic, respiratory, cardiac, gastrointestinal, urinary and renal, pulmonary embolism, wound complications, overall complications (any of the previously mentioned complications) and mortality. The ICD-9-CM codes for these complications are shown in Table 1.

Table 1. ICD-9-CM codes used for analysis

Label	Codes
Procedures (2,50):	
Hemiarthroplasty	81.81
Total shoulder arthroplasty	81.80
Reverse shoulder arthroplasty	81.88
Condition (12,14):	
Chronic obstructive pulmonary disease	490-492, 496
Complications (53,54):	
Neurological complications	997.00–997.09
Respiratory complications	518.4, 518.5, 518.81–518.84, 997.3
Cardiac complications	410, 997.1
Gastrointestinal complications	535.0, 570, 575.0, 577.0, 997.4
Urinary and renal complications	584, 997.5
Pulmonary embolism	415.1
Wound-related complications including infection, dehiscence, seroma, and hematoma	998.1, 998.3, 998.5, 998.83, 999.3

Charges and Costs

In the NIS, raw cost is data is provided as "total charges" for each admission. (55) These charges include how much the hospitals had billed for services but does not reflect how much the hospital services actually cost or how much the hospitals actually received in payment. To convert these charges into actual costs, which would reflect the actual expenses incurred during hospital services (including wages, supplies and utility costs), cost-to-charge ratios (CCR) are applied. The CCRs are supplied by the HCUP and constructed using information from the

Healthcare Cost Report Information System. (56) They then are used in conjunction with the total charges provided to calculate the hospital costs associated with inpatient hospitalization.

Statistical Analysis

The ICD-9-CM procedural and diagnosis codes in Table 1 were utilized to assess each hospitalization record for shoulder arthroplasty, COPD, comorbidities and complications. Total charges and CCR ratios were used to derive total costs. Univariate testing using weighted Student's t-tests were used to compare continuous variables and weighted chi-squared tests were used to compare categorical variables.

COPD is highly represented within the Elixhauser Comorbidity Index's chronic pulmonary disease category. In order to prevent double counting of COPD in the regression models so that the individual contribution of COPD could be assessed, the Elixhauser Comborbidity Index was adjusted by removing the chronic pulmonary disease category from the overall index score.

The multivariate regression model for each of the complications were adjusted for age, sex, race, Elixhauser Comorbidity Index, hospital size, hospital region and primary payer type. For mortality, the model was repeated again while adjusting for overall complications to assess whether the mortality rate was affected by in-hospital complications. Statistical significance was defined as $\alpha < 0.05$.

RESULTS

Question 1: Trends of COPD and Shoulder Arthroplasty

There is an upward trend in both shoulder arthroplasty and patients with COPD undergoing shoulder arthroplasty (Figure 1). In 2001, there were 21,113 cases of shoulder arthroplasty per year, which has increased to 83,210 cases per year, reflecting an 294% increase (Table 2). The overall proportion of patients undergoing shoulder COPD undergoing has been relatively steady with 8.0% in 2001 to 8.7% in 2014. However, the absolute number of patients with COPD undergoing shoulder arthroplasty has increased by 324% over the same time period, from 1,699 patients to 7,205 patients.

Figure 1. Trends of Patients with COPD Undergoing Shoulder Arthroplasty

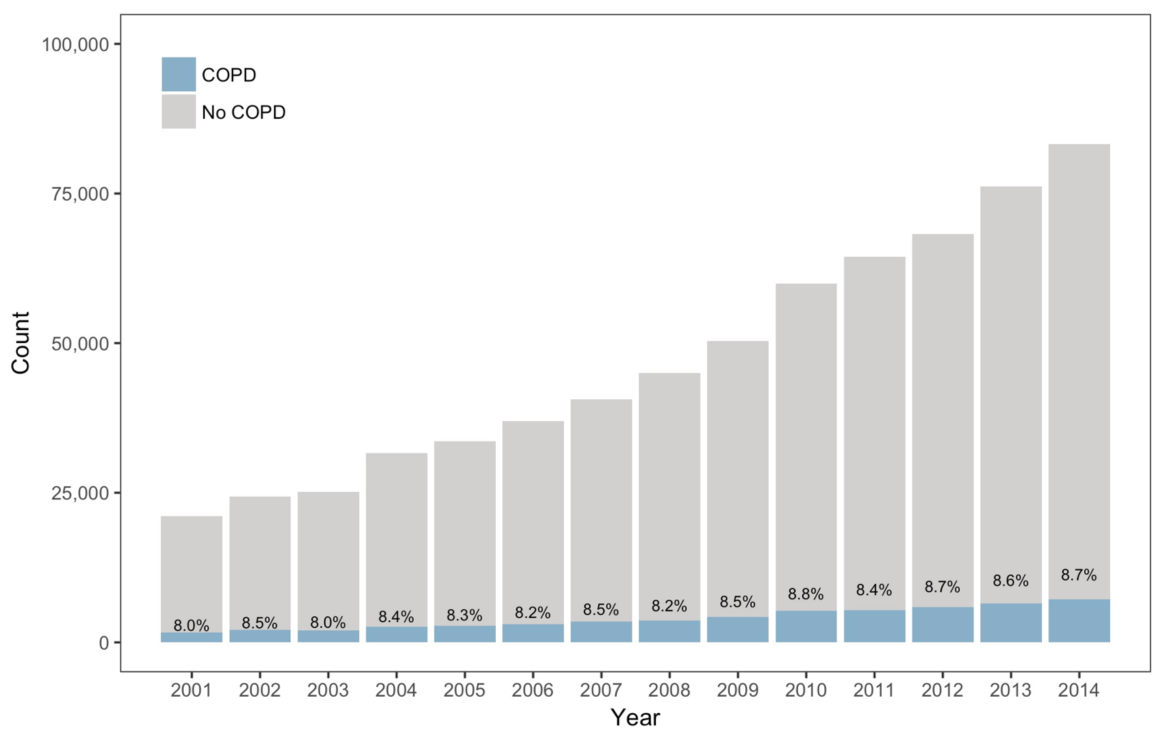

Table 2. Counts of Shoulder Arthroplasty with COPD

Year	Total	No COPD	COPD
2001	21,113	19,414	1,699
2002	24,360	22,289	2,071
2003	25,140	23,118	2,023
2004	31,623	28,974	2,649
2005	33,610	30,836	2,774
2006	37,009	33,981	3,028
2007	40,638	37,201	3,437
2008	44,989	41,312	3,677
2009	50,324	46,049	4,275
2010	59,976	54,671	5,305
2011	64,419	59,021	5,399
2012	68,260	62,330	5,930
2013	76,145	69,620	6,525
2014	83,210	76,005	7,205
Total	**660,816**	**604,820**	**55,996**

Question 2: Inpatient Outcomes of COPD Patients Undergoing Shoulder Arthroplasty

The cohort of patients who underwent shoulder arthroplasty with COPD had a statistically significantly younger mean age than those without COPD, with a difference of 2.1 years. In terms of age distribution, the COPD group had a greater proportion of patients in the 66-80 and >80 age groups and a smaller proportion of patients in the 18-45 and 46-65 age groups compared to the non-COPD group (Table 3).

The patients undergoing shoulder arthroplasty tend to be skewed more towards the female population, with both the COPD and non-COPD groups exhibiting greater proportions of female patients than male patients. In the COPD group, this gender skew was more pronounced, with 61.06% of patients being female versus 59.43% in the non-COPD group.

For the Elixhauser comorbidity index, the COPD population had a statistically significantly greater comorbidity index. However, this could possibly be due to the fact that COPD encompasses the vast majority of the "chronic pulmonary disease" component of the Elixhauser Comorbidity Index. To assess whether COPD patients had significantly different comorbidity burdens even without COPD, the "chronic pulmonary disease" component from the COPD group's Elixhauser Comorbidity Index was removed, but the COPD group still demonstrated a greater comorbidity index at 2.2 vs. 1.7 in the non-COPD group ($p < .001$).

There were a few other demographic differences between the COPD and non-COPD groups. In the COPD group, there was a slightly higher proportion of patients who were white and a lower proportion of patients who were black or Hispanic. The COPD group was more likely to have a procedure in a large hospital that the non-COPD group. Furthermore, there were relatively large differences in the payer for each of the groups. The COPD group had a higher proportion of patients with Medicare whereas the non-COPD group had a higher proportion of patients who had private insurance which included HMOs. Regionally, the largest proportion of patients was in the South, but the COPD population had a greater relative proportion in the South compared to the non-COPD group.

Table 3. Demographics

Term	No COPD N = 604,820	COPD N = 55,996	P-value	sig
Age, mean (SD)	68.8 (11.2)	70.9 (9.6)	<.001	*
Age Category, count, (%)			<.001	*
18-45	18,706 (3.09)	395 (0.71)		
46-65	190,870 (31.56)	14,794 (26.42)		
66-80	310,087 (51.27)	31,546 (56.34)		
>80	85,157 (14.08)	9,261 (16.54)		
Female, count, (%)	359,433 (59.43)	34,192 (61.06)	0.001	*
Race, count, (%)			<.001	*
White	439,558 (72.68)	42,495 (75.89)		
Black	20,693 (3.42)	1,492 (2.66)		
Hispanic	19,123 (3.16)	1,157 (2.07)		
Asian or Pacific Islander	3,110 (0.51)	113 (0.20)		
Native American	1,779 (0.29)	183 (0.33)		
Other	9,448 (1.56)	812 (1.45)		
Missing	111,108 (18.37)	9,745 (17.40)		
Hospital Bedsize, count, (%)			<.001	*
Small	104,704 (17.31)	8,493 (15.17)		
Medium	149,937 (24.79)	14,232 (25.42)		
Large	348,155 (57.56)	33,112 (59.13)		
Missing	2,023 (0.33)	159 (0.28)		
Elixhauser, mean (SD)	1.7 (1.4)	3.2 (1.4)	<.001	*
Payer, count, (%)			<.001	*
Medicare	399,354 (66.03)	43,471 (77.63)		
Medicaid	15,077 (2.49)	2,193 (3.92)		
Private including HMO	159,997 (26.45)	8,257 (14.75)		
Self-pay	4,220 (0.70)	230 (0.41)		
No charge	562 (0.09)	49 (0.09)		
Other	24,575 (4.06)	1,740 (3.11)		
Missing	1,036 (0.17)	56 (0.10)		
Hospital Region, count, (%)			<.001	*
Northeast	88,426 (14.62)	7,426 (13.26)		
Midwest	165,927 (27.43)	16,117 (28.78)		
South	217,795 (36.01)	22,503 (40.19)		
West	132,671 (21.94)	9,951 (17.77)		

In terms of comorbidities, patients with COPD had significantly higher rates of all selected comorbidities, which included congestive heart failure, depression, obesity, neurologic disorders, renal disease and liver disease. (Table 4) The greatest difference was in congestive heart failure where the proportion of patients with congestive heart failure was 7.01% greater in the COPD population than the non-COPD population. Depression had the second greatest difference in proportion, with a difference of 5.12%. For each of the other comorbidities, there was a statistically significant difference but the difference in proportions were less than 1%.

Table 4. Prevalence of Comorbidities

Term	**No COPD** N = 604,820	**COPD** N = 55,996	**P-value**	**sig**
Congestive heart failure, count, (%)	20,648 (3.41)	5,836 (10.42)	<.001	*
Depression, count, (%)	70,370 (11.63)	9,377 (16.75)	<.001	*
Obesity, count, (%)	48,564 (8.03)	4,929 (8.80)	0.003	*
Neurologic disorders, count, (%)	8,417 (1.39)	1,025 (1.83)	<.001	*
Renal disease, count, (%)	3,740 (0.62)	524 (0.94)	<.001	*
Liver disease, count, (%)	4,693 (0.78)	607 (1.08)	<.001	*

The disposition for the COPD population was significantly different from that of the non-COPD population. In the COPD population, the proportion of patients who had a routine discharge was 13.45% less than that of the non-COPD population. The COPD group also had a 9.51% greater probability of “other transfer” and a 3.27% greater chance of home health care. Additionally, COPD patients had a greater probability of mortality.

Table 5. Disposition Outcomes

Term	No COPD N = 604,820	COPD N = 55,996	P-value	sig
Disposition, count, (%)			<.001	*
Routine	390,140 (64.51)	28,593 (51.06)		
Transfer to short term hospital	1,846 (0.31)	377 (0.67)		
Other transfer	98,602 (16.30)	14,453 (25.81)		
Home health care	112,737 (18.64)	12,268 (21.91)		
Against medical advice	244 (0.04)	43 (0.08)		
Died	808 (0.13)	171 (0.31)		
Discharged alive, dest. unknown	90 (0.01)	14 (0.02)		
Missing	353 (0.06)	76 (0.14)		

The COPD population had statistically significantly greater proportions of complications than the non-COPD group in every category other than neurologic complications. (Table 6) The greatest difference was in respiratory complication, where 4.45% more COPD patients had respiratory complications. COPD patients also had a 1.76% greater probability of having a urinary or renal complication. All other complication rates were within 1% of the non-COPD population. Overall, COPD patients had a 6.11% greater chance of having a post-operative complication.

Table 6. Complication Rates

Term	No COPD N = 604,820	COPD N = 55,996	P-value	sig
Neurologic, count, (%)	633 (0.10)	82 (0.15)	0.183	
Respiratory, count, (%)	7,538 (1.25)	3,192 (5.70)	<.001	*
Cardiac, count, (%)	4,028 (0.67)	684 (1.22)	<.001	*
Gastrointestinal, count, (%)	1,542 (0.25)	224 (0.40)	0.004	*
Urinary and renal, count, (%)	11,608 (1.92)	2,061 (3.68)	<.001	*
Pulmonary embolism, count, (%)	1,326 (0.22)	285 (0.51)	<.001	*
Wound complication, count, (%)	3,090 (0.51)	403 (0.72)	0.003	*
Overall complications, count, (%)	26,451 (4.37)	5,869 (10.48)	<.001	*
Mortality, count, (%)	808 (0.13)	171 (0.31)	<.001	*

After adjusting for covariates, COPD was associated with statistically significant increased odds in all complication categories other than neurologic. (Figure 2, Table 7) COPD patients have 3.51 times greater odds of having a respiratory complication, 1.72 times greater odds of pulmonary embolism, 1.46 greater odds of cardiac complications, 1.41 times greater odds of urinary and renal complications, 1.32 times greater odds of gastrointestinal complications and 1.15 times greater odds of wound complications. COPD patients have 1.98 times greater odds of overall complications and 1.59 times greater odds of mortality. However, after adjusting for the overall complications, the increased odds ratio of mortality was no longer statistically significant.

Figure 2. Forest Plot of Complications Odds Ratios

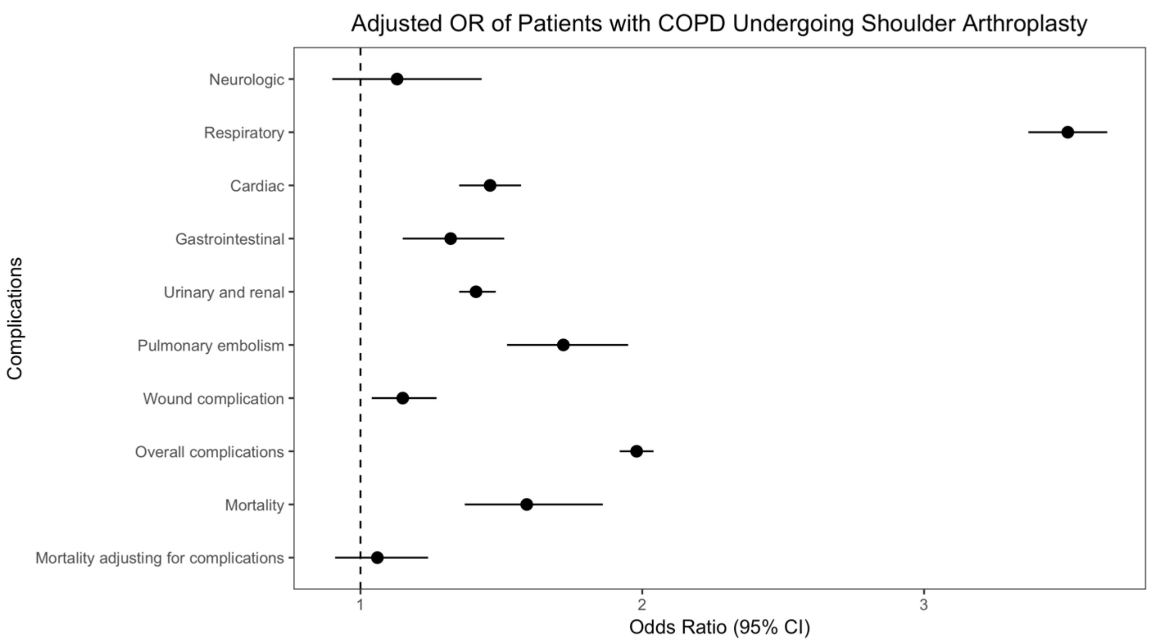

Table 7. Complications Odds Ratios

Term	OR	95% CI	P-value	sig
Neurologic	1.13	(0.90 - 1.43)	0.364	
Respiratory	3.51	(3.37 - 3.65)	<.001	*
Cardiac	1.46	(1.35 - 1.57)	<.001	*
Gastrointestinal	1.32	(1.15 - 1.51)	<.001	*
Urinary and renal	1.41	(1.35 - 1.48)	<.001	*
Pulmonary embolism	1.72	(1.52 - 1.95)	<.001	*
Wound complication	1.15	(1.04 - 1.27)	0.02	*
Overall complications	1.98	(1.92 - 2.04)	<.001	*
Mortality	1.59	(1.37 - 1.86)	<.001	*
Mortality adjusting for complications	1.06	(0.91 - 1.24)	0.508	

Question 3: How COPD Affects Costs and Length of Stay After Shoulder Arthroplasty

On average, COPD is associated with a statistically significantly greater cost of hospitalization of $1,441, which corresponds to a difference of 9.3% of the cost of the non-COPD population. COPD patients also show a statistically significant greater length of stay of 0.8 days, which is a 30.8% longer than the patients without COPD. (Table 8)

Table 8. Costs and Length of Stay

Term	No COPD N = 604,820	COPD N = 55,996	P-value	sig
Cost ($), mean (SD)	15,513 (8,880)	16,954 (9,498)	<.001	*
Length of stay (days), mean (SD)	2.6 (2.7)	3.4 (3.5)	<.001	*

DISCUSSION

The number of patients with COPD undergoing shoulder arthroplasty has continued to increase. With the continued trend of an increasing number of patients undergoing shoulder arthroplasty and COPD prevalence continuing to maintain steady, it is likely for this trend to continue into the future. Therefore, understanding the profile of complications associated with COPD in shoulder arthroplasty will be key for effective pre-operative optimization and post-operative management of these patients.

Question 1: What are the trends of patients with COPD undergoing shoulder arthroplasty?

The number of patients undergoing shoulder arthroplasty has increased dramatically. Furthermore, the proportion of patients undergoing shoulder arthroplasty has been relatively steady with a slight increase. This study showed a 294% increase from 2001 to 2014 in the number of shoulder arthroplasties being performed each year. Other studies have also found similar trends of drastic and accelerating increases in shoulder arthroplasty. In the early 1990s, there were less than 15,000 aTSAs and HAs which increased to approximately 26,000 TSA and HAs by 2003. (3) From 2003, the number of shoulder arthroplasty procedures perform increased to over 65,000 shoulder arthroplasties in 2011, when the rTSAs were split into their own ICD-9-CM code. (2) The incidence of shoulder arthroplasty continued to grow to approximately 79,000 procedures in 2014. (1)

The incidence of shoulder arthroplasty found in this study was relatively similar to previous studies. To compare, this study found 25,140 and 64,419 shoulder arthroplasties performed in 2003 and 2011, respectively. These numbers were very similar to the numbers seen by Westermann et al. and Kim et al. (2,3) These two studies also used the NIS database, however the small difference may be due to the NIS redesigns in 2012. The redesign resulted in decreased the count number by assigning new trend weights, which reduced the historical estimated counts. The numbers in this study may vary slightly from those of Palsis et al. despite the use of the same NIS database due to the fact that they limited the screen to include only primary diagnoses. (1)

While this study did not look specifically at the breakdown of what types of shoulder arthroplasties are contributing the most to the rapid increase in shoulder arthroplasty, other studies have attempted to elucidate the cause behind this trend. In November 2003, the FDA approved the rTSA for use. (3) This introduction expanded the use cases of shoulder arthroplasty. By altering the native biomechanics of the shoulder, the rTSA increased the breadth of pathology that could be effectively treated through the use of shoulder arthroplasty. Some have suggested that this event was the major change that effectively changed the rate at which shoulder arthroplasty was being performed. (3) However, due to aTSA and rTSA being coded together under the same ICD-9 code, it was impossible to separate rTSAs from aTSAs using ICD-9-CM codes alone. It was only until 2011 that rTSA started being coded under a separate ICD-9-CM code. (2,57) In the first year of the introduction of the rTSA code, 32.6% of shoulder arthroplasty procedures were due to rTSAs. (2) The more recent growth of shoulder arthroplasty is largely driven by the increasing use of rTSAs. Palsis et al. showed that with the increase in rTSAs, there was also been a decrease in both aTSAs and HAs. (1) They postulated that the large increase in rTSAs could be due to the expanding indications for rTSA, the more forgiving nature of achieving a satisfactory rTSA compared to an aTSA and a decreased concern with the longevity of rTSA components. (1)

This study found a continuous increase of patients with COPD undergoing shoulder arthroplasty from 1,699 in 2001 to 7,205 in 2014. This has been driven mainly by the increasing overall number of patients undergoing shoulder arthroplasty, and a relatively flat but slightly growing proportion of patients with COPD. This trend in terms of proportion of patients with COPD is reflective of the overall trends of COPD prevalence in the United States population. (27) However, as surgeons become more comfortable with the rTSA procedure and the use of rTSA becomes more routine, particularly for traumatic indications, the number of patients with COPD undergoing shoulder arthroplasty will likely continue to increase.

Demographics

In terms of the demographics of patients undergoing shoulder arthroplasty, the population that had COPD was generally similar to the population that did not have COPD, although there were some key differences. The average age of patients with COPD was greater by only 2.1 years. By age category, the COPD group had a greater prominence of patients in older age groups (66-80s and >80) and fewer in the younger categories (18-45 and 45-65). This is an expected finding as risk of COPD increases with increasing age, although COPD also decreases life expectancy. (59)

Both the COPD and non-COPD populations showed a gender imbalance with a greater predisposition towards females. This is likely attributable to the greater prevalence of shoulder arthroplasty in women than men, particularly in rTSA. Previous studies have shown that, rTSAs and HAs were more commonly performed in females, but the gender distribution for aTSAs were nearly equal for males and females. (2,50) In contrast to the female predominance of shoulder arthroplasty, COPD has historically been thought to be more prevalent among men than women due to higher smoking rates and more frequent workplace exposures. (60,61) However, there is evidence that women may be more susceptible to the adverse effects of smoking than men, and that there may be underdiagnosis of the condition in women due to gender bias. (60,61) Furthermore, while the prevalence of spirometrically determined COPD has decreased in men, COPD rates in women have increased. (61) Orthopedic surgeons should be aware that COPD will be an increasingly prevalent comorbidity in the gender population that is more likely to undergo shoulder arthroplasty.

COPD is strongly associated with a multitude of comorbidities. This was reflected by the significantly greater Elixhauser comorbidity index for patients with COPD, even after removal of the chronic pulmonary disease component from the index. Due to the high rate of concurrent comorbidities, it was necessary to include adjustment of the complications using the Elixhauser comorbidity index in the regressions. In this study, patients with COPD had statistically significantly higher rates of congestive heart failure, liver disease, neurologic disorders, obesity and depression. While the association of COPD with various comorbidities was demonstrated in this group of patients, it is possible that the overall comorbidity burdens seen in this population are less than what would generally be seen in the general population. Shoulder arthroplasty is often an elective procedure, so surgeon patient selection would introduce a selection bias that would selectively reduce the comorbidity burden of patients undergoing surgery.

Previous studies have shown that over 20% of patient with COPD also have concurrent CHF. (63) In this cohort of patients who underwent shoulder arthroplasty, the proportion of patients with congestive heart failure was only 10.42%. However, COPD has been associated with left ventricular dysfunction even without the overt presence of heart failure symptoms. (64) This lower percentage of patients with CHF may be due to bias from patient selection as surgeons would generally choose to avoid performing operations on sicker patients unless necessary, especially those with serious cardiac problems.

Depression has been highly correlated with COPD. (65) Depression is important as a surgical risk factor because it has been independently associated with higher complication rates and worse surgical outcomes. (66,67) In orthopedics, depression has been associated with poorer outcomes and satisfaction in ACL reconstruction and total joint arthroplasty. (67–69) In shoulder arthroplasty specifically, depression has been associated with worse patient reported outcomes. (70) Being cognizant of the high co-prevalence of COPD and depression is important because depression is a treatable but often underdiagnosed surgical risk factor. (65) Furthermore, treatment of depression can help patients achieve outcomes similar to patients without depression. (71) Being wary of this association could help surgeons to optimize patients for surgery by addressing the patient's depression as a modifiable risk factor.

While obesity has been associated with higher rates of COPD (72), in this study, the proportion of COPD patients with obesity was only slightly greater (less than 1% greater) than the proportion without COPD. Morbid obesity defined as BMIs greater than 40 has been shown to be associated with higher rates of increased operative time, increased blood loss, rates of reintervention and increased rates of infection. (73) Morbid obesity can also cause a separate restrictive ventilatory pattern characterized by premature collapse of peripheral airways which could contribute even further to possible respiratory complications. (74) In shoulder arthroplasty, the same trend has been found, where moderate obesity does not significantly contribute to postoperative complications unless patients are morbidly obese with BMIs greater than 40. (75,76)

The other comorbidity categories of neurologic disorders, renal disease and liver disease were all significantly greater in the COPD population, but the relative differences were small (all less than 0.5% different). These statistical differences were likely due to the large sample sizes and may not be clinically significant.

Question 2: What are the short-term outcomes of patients with COPD undergoing shoulder arthroplasty?

COPD was associated with a greater risk of various complications in patients undergoing shoulder arthroplasty. In particular, there was a significant increase in respiratory complications with a 4.45% greater proportion of patients having respiratory complications and an elevated odds ratio of 3.51 after adjusting for covariates. Increases in respiratory complications were also seen with COPD in other joint arthroplasties. In THA, Yakubek et al. saw an increased risk for pneumonia (OR = 4.24, $p < 0.001$), unplanned intubation (3.85, $p < 0.001$) and use of mechanical ventilator >48 hours (OR = 4.87, $p < 0.001$) (11) and Liao et al. reported an increased risk of 30-day pneumonia and 30-day acute respiratory failure. (12) In TKA, there was an increase in the odds of 90-day pneumonia, even after adjusting for sex, cardiovascular disease and CVA occurrence. (14) In VA patients with COPD who underwent surgery after a hip fracture, COPD was associated with increased rates of reintubation, failure to wean and pneumonia. (77) As COPD is primarily a pulmonary disease, it is a strong independent risk factor for post-operative respiratory complications. Therefore, increased focus on pre-operative optimization, use of multimodal analgesics for anesthesia and post-operative pulmonary rehabilitation should be pursued to reduce respiratory complication risk.

COPD was associated with an increase in odds of urinary and renal complications. This increase may possibly be due to the drugs used to treat COPD such as anticholinergics. While anticholinergics are effective for treatment of COPD symptoms, a major side effect is the possibility of urinary retention. (78) This can be especially problematic in patients already at higher risk of urinary retention such as older males due to the prevalence of benign prostatic hyperplasia. Post-operative urinary retention leads to a greater chance of urinary tract infection due to urinary stasis and increases the chances of sepsis and prolonged length of stay. (79) In THA, COPD was also associated with an increased risk of urinary tract infection (OR 1.48, $p = 0.010$) of a similar magnitude. (11)

In this study, COPD was associated with a significant increase in the risk complications overall. More specifically, in addition to respiratory and urinary and renal complications, COPD was independently associated with increased odds of cardiac (1.46), gastrointestinal (1.32), pulmonary embolism (1.72) and wound complications (1.15). Overall, there was 1.98 times greater odds of overall complications in the COPD population when compared to the non-COPD population in this study. Previous studies have found similar increases in odds of complications, Shields et. al found that pulmonary comorbidities were associated with an OR of 2.19 of major complications in shoulder arthroplasty, while the type of procedure that the patient underwent (either hemiarthroplasty and TSA) did not significantly affect the risk of major complications. (80) Furthermore, history of COPD resulted in an OR of 2.76 for any complications within 30-days, an OR of 3.42 for major complications and OR of 2.71 for minor complications in shoulder surgery. (36) Waterman et al. also found COPD to be a significant risk factor for any complications. (81) Similar trends have been seen in other orthopedic surgeries. Yakubek et al. demonstrated that COPD independently increased the risk of any complication in patients undergoing THA. (11) This increase in risk was present within 24 hours postoperatively and these patients were at higher risk if discharged after a short hospital stay. (38) Furthermore, COPD has been established as a risk factor for increased rates of 30-day readmission in patients undergoing TJA. (82)

COPD was associated with an increased risk of inpatient mortality in this study. Other studies have also established COPD as a risk factor for mortality. However, most other studies look at time periods beyond just the inpatient stay. In THA, COPD has been associated with significant increases in 30-day mortality (11) and 1-year mortality (12). In TKA, COPD was associated with increased 3-year mortality. (14) After surgical fixation of a hip fracture in geriatric patients, Wu et al found that COPD was associated with an increase in 1-year mortality. (68)

It is likely that the major cause of increased mortality in the COPD shoulder arthroplasty patients is due to post-operative complications. In this study, after adjusting for overall complications, there was no longer a statistically significant increase in mortality. This finding suggests that most of the mortality from COPD is actually due to complications after surgery. Therefore, better management to avoid post-operative complications is paramount to preventing post-operative mortality in shoulder arthroplasty patients.

It was found in this study that COPD patients were less likely to have a routine discharge and more likely to be discharged to short term hospitals, transferred to other locations, or to have home healthcare. This suggests that patients with COPD may need a longer period to recover after surgery and may need extra care in the postoperative period compared to those without COPD. Similar to the findings in this study, Yakubek et al. found that COPD was associated with non-home discharge destinations after THA. (11) Unfortunately, previous studies have found that discharge disposition may contribute to complication and readmission rates. In both TJA and shoulder arthroplasty, discharges to post-acute care facilities, skilled nursing facilities and inpatient rehabilitation facilities have been associated with higher complication rates. (24,83)

Question 3: How does COPD affect costs of care and length of stay after shoulder arthroplasty?

Cost containment has become an area of intense focus for healthcare. With the introduction of the Affordable Care Act in 2008, the "triple aim" of improving patient experience, improving the health of populations and reducing the cost of healthcare has become the guiding principle for the direction of healthcare spending in the United States. (84) To achieve these goals, the introduction of alternative payment strategies such as bundled payment systems, where healthcare providers are reimbursed a fixed amount per patient, have been introduced. This payment structure places the burden of financial risk on healthcare providers and theoretically incentivizes providers to reduce costs. (85–88) Therefore, there have been substantial efforts and increased scrutiny on defining and mitigating healthcare costs.

This study found that COPD is associated with an $1,441 increase in costs for patients undergoing shoulder arthroplasty. Hustedt et al. found that increasing comorbidity burden is associated with increased cost in TJA, with the marginal cost of COPD being $775. (22) The difference in marginal cost derived by Hustedt et al. and the difference in cost in this study could be due to the different procedures that were of focus. This study looked at shoulder arthroplasty whereas Hustedt et al. focused on TJA. Additionally, Hustedt et al. adjusted the marginal cost by other comorbidities, whereas the $1,441 in this study is unadjusted and COPD has many associated comorbidities. (22) In shoulder arthroplasty, Rosas et al. found that while comorbidities did not increase the same-day reimbursement costs, they significantly increased the subsequent 89-day and 90-day reimbursements in aTSA and rTSA patients. COPD as a comorbidity was associated with the highest increase in reimbursement costs after the comorbidities of hepatitis C and atrial fibrillation. (89) However, due to the different periods over which the studies collected cost data, direct comparison is difficult.

A common method to contain costs around a surgical procedure is to shift the procedure from inpatient to outpatient. This change has occurred in previous orthopedic procedures such as anterior cruciate ligament (ACL) reconstruction. (90,91) A systematic review found that shifting an orthopedic procedure from inpatient to outpatient is associated with an average cost savings of 17.6 – 57.6%. (91) This trend has also taken hold in arthroplasty procedures, and an increasing number of total hips and total knees are being done on an outpatient basis. (92) While outpatient shoulder arthroplasty is less common, its incidence has also been increasing. (93,94)

In this study, COPD was associated with a 0.8 day increase in length of stay. Given the greater rate of complications in this population, this increase is unsurprising as complications often take time to resolve. COPD has also been previously associated with increased lengths of stay in both THA and TKA. (12,13) Rozell et al. also determined that patients with COPD had 2.42 times greater odds of prolonged length of stay greater than 3 days after TJA. (95)

Peri-operative Management of COPD in Shoulder Arthroplasty

Given the higher rates of respiratory complications and greater mortality rates in the population with COPD, more attention should be placed on peri-operative management of shoulder arthroplasty patients. Preoperatively, pulmonary evaluation should be carefully done to ensure pre-operative optimization. COPD should be aggressively treated in patients with COPD who do not have optimal reduction of symptoms, optimal exercise capacity or airflow obstruction on physical examination. (34) Treatments for preoperative COPD patients are similar to those for non-preoperative patients. Pulmonary conditioning with combinations of bronchodilators, antibiotics, corticosteroids, smoking cessation and physical therapy can be used to optimize the pre-operative status of the patient. (97) Furthermore, elective surgeries should be postponed in the event of acute exacerbations. (34)

A prolonged operative course can also increase the risk of pulmonary complications, with general anesthesia exceeding 2.5 - 4 hours being associated with an increased risk of pulmonary complications. (98) For anesthesia, most COPD patients are usually able to tolerate tracheal intubation without any serious side effects. However, airway instrumentation or inhalation of irritants can trigger a brochoconstriction reflex that is vagally-mediated. (99) In order to reduce the chances of upper airway injuries and lung volo- or barotrauma, the use of a regional anesthetic blockade and application of a laryngeal mask or non-invasive positive pressure ventilation are viable options that should be considered. (74) Established protocols from the Enhanced Recovery After Surgery protocols could also be useful to help patients recover from surgery more quickly. These protocols stress the use of a multidisciplinary team to implement pre-operative patient education, multimodal pain control and accelerated rehabilitation. (100) In COPD patients, a multi-modal analgesic regimen could be especially useful in order to decrease respiratory depression due to anesthesia or analgesic use.

Post-operatively, pulmonary management is crucial to help avoid atelectasis that could lead to increased pulmonary complications such as pneumonia or reintubation. Use of respiratory physiotherapy techniques such as incentive spirometry, deep breathing exercises, continuous positive airway pressure (CPAP) or non-invasive positive pressure ventilation (NIPPV) can be used to prevent a fall in functional lung volume and could help to reduce pulmonary complications. (74)

Study Limitations

This study is subject to the usual limitations of database studies, including the accuracy of coding on original data entry and a limit in the amount of detail in the status of each patient. Database studies are highly dependent on the accuracy of the coding within the database. Unfortunately, after assembly and deidentification of the database entries, the accuracy of the coding is unable to be verified. This represents a significant limitation as there a wide variety of areas where error in medical coding can be introduced. (44)

As the NIS only captures data from the immediate inpatient hospitalization, this study focuses only on the immediate inpatient stay and does not capture any complications after the patient left the hospital. Due to this lack of longitudinal data, the long-term complication rate may be higher than is reported in this study. Furthermore, since the numbers of patients are so large, it is often possible achieve statistically significant results, even if they are not clinically significant. Further study of the entire care cycle, including events after discharge are necessary to fully understand what occurs after patients are discharged. (101)

Since the NIS only includes only inpatient outcomes, outpatient procedures are not included within the database. While the vast majority of shoulder arthroplasty patients still undergo the inpatient procedures, ambulatory shoulder arthroplasty is gaining traction. (93) However, this means that the trend numbers seen in this study likely underestimate the true incidence of shoulder arthroplasty.

With a complex and progressive disease such as COPD, severity of the disease state can vary dramatically between patient to patient. Therefore, simple ICD-9-CM coding does not capture or segregate between the large range of severity that COPD can encompass. It is likely that patients with greater COPD severity will experience more post-operative complications. However, this separation is unable to be captured with this database.

Future Directions

Further study of how COPD affects outcomes after shoulder arthroplasty is warranted. A future database study delineating COPD patients by severity may yield interesting results and may help clinicians focus on patients who have the greatest need for prevention of post-operative complications. FEV_1/FVC ratios or GOLD grading could be useful for such stratification, as they are already used clinically to stratify severity states of COPD. (102)

COPD may not affect all types of shoulder arthroplasty equally. Furthermore, the demographics of patients undergoing the various forms of shoulder arthroplasty differ. It may thus be interesting to pursue how COPD affects the patients undergoing the various subtypes of shoulder arthroplasty. Further splitting the patients into elective procedures and traumatic procedures may also yield interesting results, as patients who undergo elective surgery could be healthier and more likely to be optimized for surgery than the population that undergoes surgery for traumatic indications.

This study was a retrospective study of how COPD affects patients undergoing shoulder arthroplasty. The most clinically applicable future study may be a randomized controlled trial of patients undergoing shoulder arthroplasty stratified by severity and randomizing them to aggressive preoperative optimization, modified anesthetic technique and post-operative rehabilitation versus routine peri-operative care in order to see how aggressive peri-operative management of COPD affects outcomes. Such a study would help to elucidate whether or not the elevated risks of COPD in shoulder arthroplasty are modifiable.

CONCLUSIONS

There are a significant number of COPD patients undergoing shoulder arthroplasty. As the incidence of shoulder arthroplasty continues to grow, defining effective methods of perioperative management for COPD patients becomes increasingly important. Furthermore, surgeons should be cognizant of the increased risks of complications and mortality within this patient population.

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