Chronic Obstructive Pulmonary Disease Is an Independent Predictor for 30-Day Complications and Readmissions Following 1- to 2-Level Anterior Cervical Discectomy and Fusion

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Abstract

Study Design: Retrospective cohort.

Objectives: To study evidence to assess the impact of chronic obstructive pulmonary disease (COPD) on 30-day outcomes following 1- to 2-level anterior cervical discectomy and fusion (ACDF).

Methods: The 2015-2016 American College of Surgeons-National Surgical Quality Improvement Program (ACS-NSQIP) database was queried using Current Procedural Terminology (CPT) codes 22 551 (single-level) and 22 552 (additional level). Patients undergoing disc arthroplasty, multilevel (>2) fusion, posterior cervical spine surgery, and patients with fracture, tumor, and/or infection were excluded.

Results: Out of 14,835 patients undergoing an elective 1- to 2-level ACDF, 649 (4.4%) had a diagnosis of COPD at the time of the surgery. Following adjusted logistic regression analysis, prior history of COPD was significantly associated with a longer length of stay (odds ratio [OR] 1.25 [95% confidence interval (CI) 1.04-1.52]; \( P = .019 \)), superficial surgical site infection (OR 2.68 [95% CI 1.06-6.80]; \( P = .038 \)), discharge destination other than home (OR 1.49 [95% CI 1.05-2.12]; \( P = .026 \)), pneumonia (OR 4.37 [95% CI 2.42-7.88]; \( P < .001 \)), ventilator use >48 hours (OR 5.34 [95% CI 1.88-15.15]; \( P = .002 \)), unplanned reintubation (OR 3.36 [1.48-7.62]; \( P = .004 \)), and 30-day readmissions (OR 1.69 [95% CI 1.20-2.38]; \( P = .003 \)).

Conclusions: The findings of this study show that COPD patients are more likely to have postoperative complications and 30-day readmissions, despite elective ACDF itself being a low-risk surgery in general. Results show that majority of the complications were pulmonary in nature, further stressing the need for accurate medical optimization following surgery in these patients.

Keywords
ACDF, anterior cervical discectomy and fusion, COPD, chronic obstructive pulmonary disease, cervical fusion, complications, readmissions, length of stay, non–home discharge destination, pulmonary complications

Introduction

Chronic obstructive pulmonary disease (COPD) is a major cause of morbidity and mortality resulting in a significant health care and economic burden. In the United States alone, it is the third leading cause of death after heart disease and cancer,¹² with studies estimating the global mortality to be approximately 3 million deaths annually.³ COPD has a multifactorial etiology with important factors such as cigarette smoking,⁴ age,⁵ gender,⁶,⁷ genetics,⁸,⁹ infections,¹⁰ underlying chronic bronchitis,¹¹ and occupational exposure to harmful gases.¹² With an increase in longevity and the higher odds of being exposed to the aforementioned risk factors, the prevalence of patients presenting to hospitals with COPD as a comorbidity...
diagnosis is gradually increasing. With an increasing trend in surgeries such as cervical fusions being done for degenerative pathologies in the elderly, COPD may complicate the postoperative course significantly. Though few studies have identified COPD as a surgical risk factor, no study has comprehensively investigated the independent impact of COPD on postoperative outcomes following anterior cervical discectomy and fusion (ACDF).

Using a large national surgical database, we aimed to determine whether COPD is associated with a higher odds of 30-day complications following ACDF and whether the presence of COPD as a comorbidity independently affects 30-day readmissions and reoperations following ACDF.

Materials and Methods

Database

This was a retrospective study done using the 2015-2016 American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) database. The ACS-NSQIP database collects surgical information from more than 500 hospitals across the United States. Data is recorded for more than 150 preoperative, intraoperative, and postoperative variables up to 30 days following the operation. The data is collated by trained surgical and clinical reviewers with audit reports showing an interreviewer disagreement rate of below 2%. Since the ACS-NSQIP database is a de-identified public database available to participating hospitals, it was exempt from the institutional review board approval.

Study Population

Current Procedural Terminology (CPT) codes for ACDF (CPT 22551) were used to retrieve records from the database. Two-level ACDFs were queried using CPT 22552 to identify each additional level. Patients undergoing additional posterior cervical spine procedures (instrumentation, laminectomy, foraminotomy, etc) were excluded from the analysis. In addition, patients undergoing >2-level fusion, fracture fixation, and fusion for malignancy were excluded. Data was filtered to remove for missing variables to prevent confounding in analysis later on. Only elective 1- to 2-level ACDFs being done for degenerative pathologies of the spine were included in the study.

Definition of Variables Studied

For baseline clinical characteristics and demographics of the study population, the following variables were collected: age (dichotomized into <65 years and ≥65 years of age), gender, body mass index (BMI), comorbidities, type of anesthesia used (general, regional, and other), admission status (inpatient vs outpatient), American Society of Anesthesiologists (ASA) class, quarter of admission (January-March, April-June, July-September, and October-December), number of levels fused (1-level vs 2-level), total operative time (minutes), and length of stay (≤1 day vs >1 day).

Thirty-day complications as defined by ACS-NSQIP were recorded. They included surgical site infection (SSI; which was divided into superficial, deep, and organ/space infections), wound dehiscence, myocardial infarction (MI), cardiac arrest, deep venous thrombosis, pneumonia, pulmonary embolism, urinary tract infection, postoperative ventilator use >48 hours, unplanned reintubation, bleeding requiring transfusion, acute renal failure, cerebrovascular/stroke, sepsis, septic shock, return to operating room within 30 days of surgery, 30-day readmissions, and 30-day unplanned reoperations.

We assessed discharge destination. The variable was dichotomized into non-home versus home cohorts. The non-home cohort included discharge to skilled care facilities, unskilled facilities, rehabilitation facilities, assisted living/elderly home facilities, separate acute care units, and death as discharge disposition.

Statistical Analysis

To identify significant predictors, Pearson $\chi^2$ test for categorical variables and Mann-Whitney U test for continuous variables were used to assess for preoperative and postoperative variables that were significantly different in the 2 groups. A backward elimination logistic regression analysis was performed to estimate the risk of COPD on 30-day complications, while adjusting for all baseline demographic and clinical variables to ensure outcome of multivariate logistic regression was reflective of the independent impact of COPD alone.

For all statistical tests, a $P$ value of less than .05 was considered significant. Statistical analysis was carried out using SPSSv23 (IBM, Armonk, NY).

Results

A total of 14,835 patients were included in the study. Six hundred and forty-nine (4.4%) patients had a prior diagnosis of COPD at the time of the surgery. Baseline clinical characteristics are shown in Table 1. Bivariate analysis showed that the groups were significantly different in terms of age, gender, BMI, comorbidities, ASA class, and admission status.

Bivariate analysis showed postoperatively patients with COPD were significantly associated with a longer length of stay >1 day ($P < .001$), superficial SSI ($P = .031$), myocardial infarction ($P = .034$), pneumonia ($P < .001$), postoperative mechanical
On adjusted analysis, prior history of COPD was significantly associated with a longer length of stay (odds ratio

| Table 2. Univariate Regression Analysis for Significant Complications Associated With Prior Existence of COPD. | With COPD | Without COPD | P  |
|---------------------------------------------------------------------------------------------------------|-----------|--------------|----|
| Length of stay (days)                                                                                     | 1.0 [1.0-2.0] | 1.0 [1.0-1.0] |<.001 |
| 0-1 days                                                                                                   | 430 (66.3%) | 10785 (76.0%) |<.001 |
| >1 days                                                                                                    | 219 (33.7%) | 3401 (24.0%)  |
| Anesthesia type                                                                                           | General    | 649 (100%)   | .107 |
| Deep SSI                                                                                                   | 0          | 21 (0.1%)    | .107 |
| Urinary tract infection                                                                                    | 5 (0.8%)   | 67 (0.5%)    | .753 |
| Postoperative ventilator use >48 hours                                                                    | 0          | 25 (0.2%)    | .284 |
| Unplanned reoperations within 30 days of surgery                                                          | 42 (6.5%)  | 395 (2.8%)   |<.001 |
| 30-Day unplanned reoperations                                                                            | 9 (1.4%)   | 178 (1.3%)   | .768 |
| Discharge destination                                                                                     | Non-home   | 50 (7.7%)    |<.001 |
| Home                                                                                                      | 599 (92.3%)| 13709 (96.6%)|    |

Abbreviations: COPD, chronic obstructive pulmonary disease; SSI, surgical site infection.
*Values in bold are statistically significant.

ventilation for more than 48 hours (P = .001), unplanned reintubation (P < .001), bleeding requiring transfusion (P = .025), acute renal failure (P = .002), having any complication within 30 days (P < .001), 30-day readmissions (P < .001), and a non-home discharge destination (P < .001; Table 2).

On adjusted analysis, prior history of COPD was significantly associated with a longer length of stay (odds ratio

| Table 1. Baseline Clinical Characteristics Between COPD and Control (Non-COPD) Groups.a | With COPD | Without COPD | P  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|--------------|----|
| Variable                                                                                                                                                | Age (years) | Gender       | .14 |
|                                                                                                                                                    | <65        | Male         | 291 (44.8%) | 5709 (49.8%)  |
|                                                                                                                                                    | ≥65        | Female       | 358 (55.2%) | 7127 (50.2%)  |
| Body mass index (kg/m²)                                                                             | <25.0      | 143 (22.0%)  | 2720 (19.2%) |
|                                                                                                                                                    | 25.0-29.9  | 182 (28.0%)  | 4679 (33.0%) |
|                                                                                                                                                    | 30.0-35.0  | 152 (23.4%)  | 3783 (26.7%) |
|                                                                                                                                                    | >35.0      | 172 (26.5%)  | 3004 (21.2%) |
| Comorbid                                                                                                                                             | Diabetess  | 670 (10.8%)  | 772 (5.4%)    |
|                                                                                                                                                    | IDDM       | 77 (11.9%)   | 1449 (10.2%) |
|                                                                                                                                                    | No         | 502 (77.3%)  | 11965 (84.3%)|
| Smoker within past year                                                                               | 355 (54.7%)| 3655 (25.7%) |
| Dyspnea                                                                                                                                             | At rest    | 20 (3.1%)    | 22 (0.2%)     |
|                                                                                                                                                    | At moderate exertion | 165 (25.4%)  | 521 (3.7%)    |
|                                                                                                                                                    | No         | 464 (71.5%)  | 13643 (96.2%) |
| Functional status prior to surgery                                                                       | Totally dependent | 1 (0.2%)    | 8 (0.1%)     |
|                                                                                                                                                    | Partially dependent | 21 (3.2%)   | 153 (1.1%)   |
|                                                                                                                                                    | Unknown    | 5 (0.8%)     | 60 (0.4%)    |
|                                                                                                                                                    | Independent | 622 (95.8%)  | 13965 (98.4%)|
| Ventilator dependent                                                                                  | 1 (0.2%)   | 0            |
| Ascites                                                                                               | 0          | 2 (0.2%)     |
| Congestive heart failure in 30 days before surgery                                                     | 2 (0.3%)   | 20 (0.1%)    | .279 |
| Hypertension requiring medication                                                                        | 429 (66.1%)| 6253 (44.1%) |
| Acute renal failure                                                                                   | 0          | 2 (0.2%)     | .762 |
| Preoperative dialysis                                                                                 | 6 (0.9%)   | 12 (0.1%)    |<.001 |
| Chronic steroid use                                                                                   | 41 (6.3%)  | 460 (3.2%)   |<.001 |
| Bleeding disorders                                                                                     | 15 (2.3%)  | 140 (1.0%)   |<.001 |
| Transfusion of at least 1 unit of packed RBCs within 72 hours before surgery                          | 0          | 1 (0.2%)     | .831 |
| Prior sepsis                                                                                           | 0          | 1 (0.2%)     | .066 |
| Prior SIRS                                                                                             | 4 (0.6%)   | 27 (0.2%)    |
| >10% weight loss in last 6 months                                                                       | 645 (99.4%)| 14158 (99.8%)|
| ASA class                                                                                              | I          | 0            | 553 (3.9%)    |
|                                                                                                                                                    | II         | 116 (17.9%)  | 7954 (56.1%) |
|                                                                                                                                                    | III        | 487 (75.0%)  | 5499 (38.8%) |
|                                                                                                                                                    | IV         | 46 (7.1%)    | 179 (1.3%)   |
|                                                                                                                                                    | V          | 0            | 1 (0.0%)     |
| Admission status                                                                                      | Inpatient  | 510 (78.6%)  | 9335 (70.0%) |
|                                                                                                                                                    | Outpatient | 139 (21.4%)  | 4251 (30.0%) |
| Total operative time (minutes)                                                                         | 121.1 ± 57.7| 118.9 ± 59.7| .388 |

Abbreviations: COPD, chronic obstructive pulmonary disease; IDDM, insulin-dependent diabetes mellitus; NIDDM, non–insulin-dependent diabetes mellitus; RBC, red blood cell; SIRS, systemic inflammatory response syndrome; ASA, American Society of Anesthesiologists.
*Values in bold are statistically significant.
**Table 3. Adjusted Analysis of Significant Postoperative Complications in COPD Patients Undergoing 1- to 2-Level ACDF.**

| Dependent Variables          | OR [95% CI]       | P |
|------------------------------|-------------------|---|
| Length of stay (days) >1 day | 1.25 [1.04-1.52]  | .019 |
| Superficial SSI              | 2.68 [1.06-6.80]  | .038 |
| Discharge destination        |                   |    |
| Non-home                     | 1.49 [1.05-2.12]  | .026 |
| Pneumonia                    | 4.37 [2.42-7.88]  | <.001 |
| Ventilator use >48 hours     | 5.34 [1.88-15.15] | .002 |
| Unplanned reintubation       | 3.36 [1.48-7.62]  | .004 |
| 30-Day readmission           | 1.69 [1.20-2.38]  | .003 |

Abbreviations: COPD, chronic obstructive pulmonary disease; ACDF, anterior cervical discectomy and fusion; OR, odds ratio; CI, confidence interval; SSI, surgical site infection; BMI, body mass index; SIRS, systemic inflammatory response syndrome; ASA, American Society of Anesthesiologists.

Each postoperative complication category was entered into a backward elimination multivariate logistic regression model while adjusting for age, gender, BMI, comorbidities (diabetes, smoking, dyspnea, functional health status prior to surgery, ventilator dependent, ascites, congestive heart failure in 30 days before surgery, hypertension requiring medication, preoperative acute renal failure, preoperative dialysis, chronic steroid use, bleeding disorders, transfusions, prior sepsis/SIRS, >10% weight loss in last 6 months), ASA class, admission status, total operative time, and anesthesia type. Values in bold are statistically significant.

[OR] 1.25 [95% confidence interval (CI) 1.04-1.52]; P = .019), superficial SSI (OR 2.68 [95% CI 1.06-6.80]; P = .038), discharge destination other than home (OR 1.49 [95% CI 1.05-2.12]; P = .026), pneumonia (OR 4.37 [95% CI 2.42-7.88]; P < .001), ventilator use >48 hours (OR 5.34 [95% CI 1.88-15.15]; P = .002), unplanned reintubation (OR 3.36 [1.48-7.62]; P = .004), and 30-day readmissions (OR 1.69 [95% CI 1.20-2.38]; P = .003; Table 3).

**Discussion**

The current study findings show that COPD is an independent factor significantly associated with a longer length of stay and a higher risk of postoperative 30-day complications and readmission. This supports the critical need for an increased focus toward preoperative management and a multidisciplinary approach involving hospitalists, surgeons, and critical care specialists toward medical optimization.

A majority of the 30-day complications affected the pulmonary system, including pneumonia, mechanical ventilation/ventilator use for more than 48 hours postoperatively, and unplanned reintubations. Airway inflammation and narrowing and/or obliteration in COPD results in the intrinsic and extrinsic respiratory muscles being overworked to compensate for the low amount of oxygen entering the alveoli. Therefore, these patients might require prolonged postoperative mechanical ventilation to maintain adequate oxygen saturation levels. The small airway disease can lead to trapping of bacteria and form a nidus of infection in the lung predisposing patients to developing pneumonia. A recent study investigating reintubations after planned extubation in 88 COPD patients revealed that analgesic and sedative use prior to planned extubation was associated with a higher risk of having a planned reintubation. A more judicious and limited use of sedatives and analgesics prior to extubation in COPD patients may be an effective way of reducing this complication.

Myelopathy has also been known to affect lung function, with studies indicating the patients with chronic cervical myelopathy may have impaired expiratory flow. This may further exacerbate underlying COPD symptoms. Physicians and surgeons should stress the need for a more intensive form of the usual lung recovery protocol, consisting of strict intensive spirometry, chest physiotherapy, and noninvasive positive pressure breathing techniques, following fusions in myelopathic patients to prevent complications.

A recent study by Walid et al showed that COPD was associated with a longer length of hospital stay and charges in ACDF female patients. Though the ACS-NSQIP does not record hospital charges, the findings of our study showing a longer length of stay may result in higher hospital charges. Capua et al also concluded that the presence of a pulmonary comorbidity was associated with a longer length of stay following elective ACDF. However, they combined both preoperative ventilator use and the presence of COPD into one variable defined as “presence of pulmonary comorbidity.” Their finding of prolonged length of stay may or may not be directly related to COPD itself.

For various orthopedic procedures, complications and extended length of hospital stay are important drivers of costs of total episode of care. Minhas et al reported that length of stay was tied to an approximate increase of $1551/per additional day. As we move toward a value-based health care system, which defines its foundations on promoting quality while minimizing expenditures, caregivers and providers should focus on the prevention of these complications in an attempt to minimize the costs associated with hospital stays.

There are several limitations to the current study. The NSQIP database only captures complications occurring up to 30 days following the index procedure. It is plausible that there may be COPD-associated complications occurring beyond the specified time period. As with any database study, we were unable to study disease severity, radiographic findings, and patient reported outcomes. The data does not contain specific clinical information with regard to preoperative and postoperative anesthetic regimens and opioid usage. We were also unable to measure health care costs from this database. Finally, the ACS-NSQIP database largely consists of academic medical centers and may not be representative of a true national population. Despite the limitations posed by the database, the current study utilizes a large cohort and effectively highlights the increased risk of adverse outcomes in these patients.

**Conclusion**

The study reveals that COPD is independently associated with a higher risk of prolonged length of hospital stay, postoperative complications, and readmission within 30 days after 1- to 2-level ACDF. This data from a large cohort of patients may be used for preoperative counseling to convey the risk of
complications and readmissions in patients with COPD after ACDF. These findings are also important in determining appropriate risk adjustment. Specific focus on optimization of patients with COPD will be beneficial in reducing the risk of postoperative complications.

**Authors’ Note**
The American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

**Declaration of Conflicting Interests**
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**References**
1. Center for Disease Control and Prevention. Leading causes of death. https://www.cdc.gov/nchs/fastats/leading-causes-of-death.htm. Accessed March 12, 2018.
2. Hoyert DL, Xu J. Deaths: preliminary data for 2011. Natl Vital Stat Rep. 2012;61:1-51.
3. GBD 2013 Mortality and Causes of Death Collaborators. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet. 2015;385:117-171.
4. Mannino DM, Higuchi K, Yu TC, et al. Economic burden of COPD in the presence of comorbidities. Chest. 2015;148:138-150.
5. Mercado N, Ito K, Barnes PJ. Accelerated ageing of the lung in COPD: new concepts. Thorax. 2015;70:482-489.
6. Foreman MG, Zhang L, Murphy J, et al; COPDGene Investigators. Early-onset chronic obstructive pulmonary disease is associated with female sex, maternal factors, and African American race in the COPDGene Study. Am J Respir Crit Care Med. 2011;184:414-420.
7. Varela MVL, de Oca MM, Halbert RJ, et al; PLATINO Team. Sex-related differences in COPD in five Latin American cities: the PLATINO study. Eur Respir J. 2010;36:1034-1041.
8. Stoller JK, Aboussouan LS. Alpha-antitrypsin deficiency. Lancet. 2005;365:2225-2236.
9. Hunninghake GM, Cho MH, Tesfaigzi Y, et al. MMP12, lung function, and COPD in high-risk populations. N Engl J Med. 2009;361:2599-2608.
10. Sethi S. Infection as a comorbidity of COPD. Eur Respir J. 2010;35:1209-1215.
11. Kim Y, Criner GJ. Chronic bronchitis and chronic obstructive pulmonary disease. Am J Respir Crit Care Med. 2013;187:228-237.
12. Boschetto P, Quintavalle S, Miotto D, Lo Cascio N, Zeni E, Mapp CE. Chronic obstructive pulmonary disease (COPD) and occupational exposures. J Occup Med Toxicol. 2006;1:11.
13. Chan KY, Li X, Chen W, et al; Global Health Epidemiology Research Group (GHERG). Prevalence of chronic obstructive pulmonary disease (COPD) in China in 1990 and 2010. J Glob Health. 2017;7:020704.
14. Marquez-Lara A, Nandyala SV, Fineberg SJ, Singh K. Current trends in demographics, practice, and in-hospital outcomes in cervical spine surgery: a national database analysis between 2002 and 2011. Spine (Phila Pa 1976). 2014;39:476-481.
15. American College of Surgeons National Surgical Quality Improvement Program. User guide for the 2016 ACS NSQIP Participant Use Data File (PUF). https://www.facs.org/~media/files/quality%20programs/nsqip/nsqip_puf_userguide_2016.aspx. Published October 2017. Accessed March 12, 2018.
16. Klimathianaki M, Vaporidou K, Georgopoulous D. Respiratory muscle dysfunction in COPD: from muscles to cell. Curr Drug Targets. 2011;12:478-488.
17. Singh D. Small airway disease in patients with chronic obstructive pulmonary disease. Tuberc Respir Dis (Seoul). 2017;80:317-324.
18. Sethi S, Murphy TF. Bacterial infection in chronic obstructive pulmonary disease in 2000: a state-of-the-art review. Clin Microbiol Rev. 2001;14:336-363.
19. Nantsupawat N, Nantsupawat T, Limswat C, Sutamtewagul G, Nugent K. Factors associated with reintubation in patients with chronic obstructive pulmonary disease. Qual Manag Health Care. 2015;24:200-206.
20. Toyoda H, Nakamura H, Konishi S, Terai H, Takaoka K. Does chronic cervical myelopathy affect respiratory function? J Neurosurg Spine. 2004;1:175-178.
21. Walid MS, Zaytseva NV. The impact of chronic obstructive pulmonary disease and obesity on length of stay and cost of spine surgery. Indian J Orthop. 2010;44:424-427.
22. Di Capua J, Somani S, Kim JS, et al. Predictors for patient discharge destination after elective anterior cervical discectomy and fusion. Spine (Phila Pa 1976). 2017;42:1538-1544.
23. Minhas SV, Chow I, Jenkins TJ, Dhingra B, Patel AA. Preoperative predictors of increased hospital costs in elective anterior cervical fusions: a single-institution analysis of 1,082 patients. Spine J. 2015;15:841-848.