Original Article

AO SPINE

Global Spine Journal
2022, Vol. 12(8) 1647–1654
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DOI: 10.1177/21925682220984469
journals.sagepub.com/home/gsj

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Respiratory Compromise After Anterior Cervical Spine Surgery: Incidence, Subsequent Complications, and Independent Predictors

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Abstract

Study design: Retrospective cohort study.

Objective: Respiratory compromise (RC) is a rare but catastrophic complication of anterior cervical spine surgery (ACSS) commonly due to compressive fluid collections or generalized soft tissue swelling in the cervical spine. Established risk factors include operative duration, size of surgical exposure, myelopathy, among others. The purpose of this current study is to identify the incidence and clinical course of patients who develop RC, and identify independent predictors of RC in patients undergoing ACSS for cervical spondylosis.

Methods: A large, prospectively-collected registry was used to identify patients undergoing ACSS for spondylosis. Patients with posterior cervical procedures were excluded. Baseline patient characteristics were compared using bivariate analysis, and multivariate analysis was employed to compare postoperative complications and identify independent predictors of RC.

Results: 298 of 52,270 patients developed RC (incidence 0.57%). Patients who developed RC had high rates of 30-day mortality (11.7%) and morbidity (75.8%), with unplanned reoperation and pneumonia the most common. The most common reason for reoperations were hematoma evacuation and tracheostomy. Independent patient-specific factors predictive of RC included increasing patient age, male gender, comorbidities such as chronic cardiac and respiratory disease, preoperative myelopathy, prolonged operative duration, and 2-level ACCFs.

Conclusion: This is among the largest cohorts of patients to develop RC after ACSS identified to-date and validates a range of independent predictors, many previously only described in case reports. These results are useful for taking preventive measures, identifying high risk patients for preoperative risk stratification, and for surgical co-management discussions with the anesthesiology team.

Keywords

ACDF, respiratory, complications, cervical spine, intubation

Introduction

Anterior cervical spine surgery (ACSS) including anterior cervical discectomy and fusion (ACDF), corpectomy and fusion (ACCF), and cervical disc arthroplasty (CDA) offer a robust variety of treatment options for cervical spondylosis with anterior pathology such as disc herniation and disc-osteophyte complexes.[1] ACDF remains the most commonly performed anterior-based procedure with over 100,000 cases performed

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in 2013,[2] and is a well-tolerated procedure with high reports of patient satisfaction and improvements in functional scores.[3] However, there are a number of rare but potentially catastrophic complications that can occur in the immediate perioperative period, including injury to the dura, vertebral artery, laryngeal nerve, esophagus, and trachea.[4-7] These injuries can lead to fluid collections (hematoma, cerebrospinal fluid), generalized soft tissue swelling, and more rarely, direct injury to the phrenic nerve or instrumentation failure resulting in airway compression.[8-11] As a result, patients undergoing ACSS may experience respiratory compromise (RC), manifesting as failure to wean from the ventilator postoperatively or emergent, unplanned reintubations. The reported incidence of RC ranges from 0% to 6.1%, with studies ranging from retrospective single-surgeon reports to multi-institutional studies.[12-14] Numerous risk factors for RC have been previously described, for instance, Sagi et al. reported on 19 patients who developed RC and identified exposure of $\geq$ 3 vertebral bodies, blood loss $\geq$ 500 milliliters, operative duration $>$ 5 hours, and upper cervical spine exposure as risk factors. In contrast, a case report by Emery et al. on 7 myelopathic patients who developed RC identified corpectomies, smoking history, and preoperative respiratory disease as risk factors.[8]

Current literature regarding RC consists primarily of retrospective, single-institution studies that are likely underpowered given the infrequent rate at which RC occurs, and often with various studies finding contradictory predictors of RC. Larger studies utilizing national registries are also lacking as they either focus on one particular type of anterior cervical spine surgery (e.g. only ACDF) or do not fully assess the breadth of variables that may be associated with RC. The purpose of this current study is to utilize a large, national, prospectively-collected registry to identify the incidence and clinical course of patients who develop RC, as well as identify independent patient-specific and operative predictors of RC in patients undergoing ACSS for cervical spondylosis.

Methods

Data Source

This study was a retrospective cohort of prospectively collected data by the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) between 2011-8. In 2018, there were over one million unique surgical procedures collected in this registry from 722 clinical sites and consisting of over 270 variables.[15] Participating clinical sites range from community centers to academic hospitals, and procedures at these sites are randomly selected for inclusion in the registry. Patients are followed prospectively from hospital admission up to 30-days after their procedure, regardless of the date of discharge. All data is collected by trained surgical clinical reviewers that manually enter and periodically audit the data to ensure accuracy. As a result, the ACS-NSQIP has high data accuracy and inter-rater reliability,[16-18] and has been used extensively in orthopedics outcomes-based research.[19-22]

Patient Identification

All patients who underwent ACSS were identified using Current Procedural Terminology (CPT codes). Patients who underwent a single-level ACDF were identified using CPT code 22551, and multi-level ACDF with the addition of CPT code 22552. Those who underwent single- and multi-level ACCF were identified using CPT code 63081 and 63082, and those who underwent a CDA were identified using CPT code 22856 with or without 22858 *(SDC I)*. CDA cases were not stratified by number of levels performed due to a limited sample size with multi-level procedures. Only patients with a surgical indication of cervical spondylosis were included in this study by manually screening postoperative International Classification of Disease (ICD) Codes to identify a diagnosis of spondylosis with or without myelopathy (*SDC II)*. Any patient who underwent a hybrid procedure (e.g. one-level ACDF and one-level CDA) were excluded. Patients who underwent any posterior cervical procedures including fusion, discectomy, uninstrumented, or instrumented fusion were excluded (Figure 1). Finally, patients with missing baseline patient-specific or operative characteristics were excluded. Anterior plate utilization was identified by using CPT code 22845-7.

Preoperative Characteristics and Postoperative Outcomes

RC was defined as failure to extubate from ventilator within 48 hours of surgery or emergent, unplanned reintubation within 30 days after surgery. Baseline patient-specific and operative characteristics were identified for each patient. Patient-specific characteristics included patient age, gender, ethnicity (white, black, other), body mass index (BMI, calculated from patient height and weight), medical comorbidities (hypertension, smoking history, diabetes mellitus, dyspnea, chronic obstructive pulmonary disease [COPD], preoperative corticosteroid use, bleeding disorders, congestive heart failure), baseline functional status, and a diagnosis of preoperative myelopathy. Operative characteristics included operative duration, procedure performed (ACDF [1-, 2-, and 3-levels], ACCF [1- and 2-levels], and CDA), anterior plate instrumentation, ambulatory surgery (defined as a length of stay of zero days), and American Society of Anesthesiologists (ASA) classification. Postoperative outcomes included any complication, which was an aggregate of the following complications: death, cardiac or renal complications, pneumonia, unplanned return to the operating room, deep vein thrombosis, stroke, sepsis, wound infection or dehiscence, and urinary tract infection. Additional outcome variables assessed included perioperative blood transfusions, unplanned hospital readmission, and non-home discharge.

Statistical Analysis

Statistical analysis was performed using SPSS version 25 (IBM Corp., Armonk, NY) and R version 3.6.3 (R Core Team,

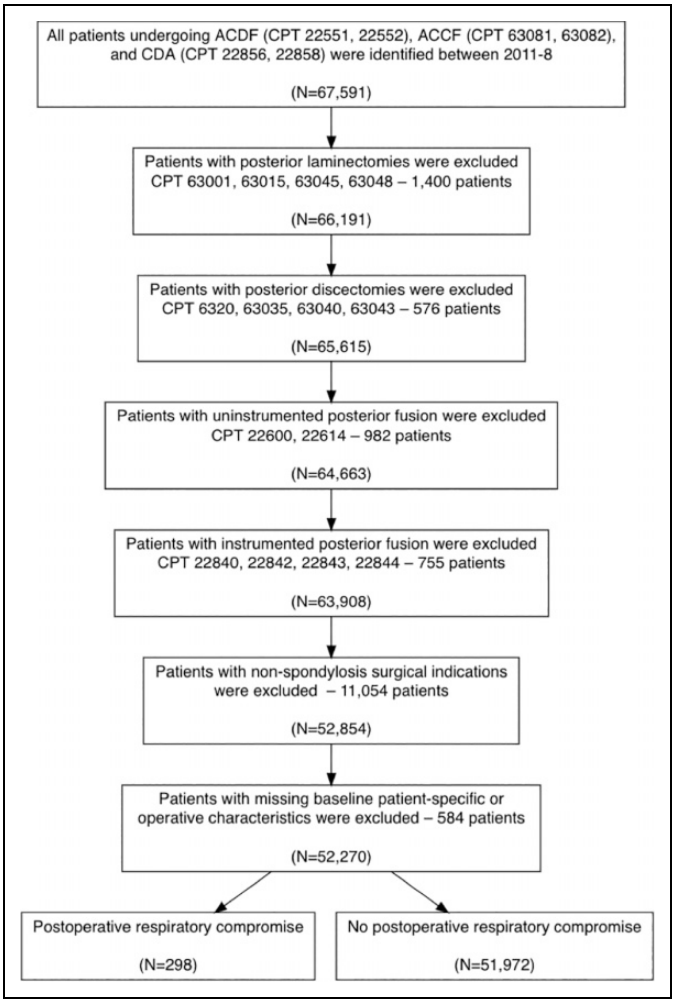

Figure 1. STROBE diagram of included patients. ACDF: Anterior cervical discectomy and fusion; ACCF: Anterior cervical corpectomy and fusion; CDA: Cervical disc arthroplasty.

2020).[23] Baseline patient-specific/operative characteristics and postoperative complications were compared using bivariate analysis. Any baseline patient-specific/operative characteristic with $P < 0.200$ was adjusted for in a multivariate analysis. Binary logistic multivariate models were used to compare postoperative complications and to identify independent predictors of RC. Statistical significance was defined as $P < 0.050$.

Results

298 patients developed RC after ACSS and 51,972 did not develop RC, with a total incidence of 0.57% (Table 1). Patients who developed RC were more likely to be older, male, non-white or non-black ethnicity, have a history of hypertension, diabetes mellitus, preoperative dyspnea or corticosteroid use ($P = 0.006$), COPD, bleeding disorders, and congestive heart failures. They had higher rates of preoperative myelopathy, longer operative duration, were more likely to undergo 2-level ACCFs, had higher ASA classifications, and were less likely to have had an ambulatory surgery ($P < 0.001$ for all comparisons, unless otherwise noted). 171 patients remained intubated >48 hours after surgery and 113 of these patients (66.1%) required subsequent reintubation after extubation. 127 patients

Table 1. Comparison of Patient-Specific Characteristics by Postoperative Respiratory Complication Status.

	All patients	Postoperative respiratory complication		
		Yes	No	*P*-value
Number of patients	52,270	298	51,972	
Patient-Specific Characteristics				
Age				< **0.001** †
< 50	37.3%	12.8%	37.5%	
51-60	32.5%	28.5%	32.5%	
61-70	20.9%	31.2%	20.9%	
> 70	9.2%	27.5%	9.1%	
Female %	50.1%	34.9%	50.2%	< **0.001** †
Ethnicity				< **0.001** †
White	80.1%	70.8%	80.2%	
Black	1.8%	1.0%	1.8%	
Other or not reported	18.1%	28.2%	18.0%	
Body mass index *(kg/m²)*				0.033
Non-obese (< 30)	53.9%	53.7%	53.9%	
Obese I (30-34.9)	25.7%	20.8%	25.7%	
Obese II (35-39.9)	12.5%	13.8%	12.5%	
Obese III (> 40)	7.9%	11.7%	7.9%	
Comorbidities				
Hypertension	45.3%	71.8%	45.1%	< **0.001** †
Smoking history	27.3%	31.5%	27.3%	0.102
Diabetes mellitus	16.0%	34.2%	15.9%	< **0.001** †
Dyspnea	5.1%	12.4%	5.1%	< **0.001** †
COPD	4.5%	14.1%	4.5%	< **0.001** †
	3.2%	6.0%	3.2%	**0.006** †
Preoperative corticosteroid use				
Bleeding disorder	1.1%	4.4%	1.1%	< **0.001** †
Congestive heart failure	0.2%	2.0%	0.0%	< **0.001** †
Dependent functional status	1.7%	14.8%	1.6%	< **0.001** †
Preoperative myelopathy	38.1%	54.7%	38.0%	< **0.001** †
Operative Characteristics				
Operative duration *(hours)*				< **0.001** †
< 2	56.2%	35.2%	56.3%	
2-3	28.0%	29.5%	28.0%	
> 3	15.8%	35.2%	15.7%	
Procedure				< **0.001** †
ACDF (# of levels)				
One	45.0%	35.9%	45.0%	
Two	37.1%	35.9%	37.1%	
Three or more	5.8%	9.7%	5.7%	
ACCF (# of levels)				
One	3.7%	8.1%	3.7%	
Two or more	3.3%	9.1%	3.2%	
CDA	5.2%	1.3%	5.3%	
Anterior plate instrumentation	68.1%	69.5%	68.1%	0.620
Ambulatory surgery	8.4%	2.0%	8.4%	< **0.001** †
ASA classification				< **0.001** †
I or II	57.6%	23.8%	57.7%	
III or IV	42.4%	76.2%	42.3%	

† Significance defined as p < 0.05, significant values are in bold.
COPD: Chronic Obstructive Pulmonary Disease, ASA: American Society of Anesthesiologists; ACDF: Anterior cervical discectomy and fusion; ACCF: Anterior cervical corpectomy and fusion; CDA: Cervical disc arthroplasty.

Table 2. Comparison of 30-Day Complications by Postoperative Respiratory Complication Status.

	All Patients	Postoperative respiratory complication		Bivariate analysis	Multivariate analysis		
		Yes	No				
	52,270	298	51,972	*P*-value	OR	95% CI	*P*-value
Any complication	3.07%	75.8%	2.66%	< 0.001 †	73.4	55.3-97.4	< **0.001** †
Death	0.15%	11.7%	0.08%	< 0.001 †	51.5	30.6-86.9	< **0.001** †
Cardiac complications	0.22%	19.5%	0.11%	< 0.001 †	105.8	68.3-164.0	< **0.001** †
Renal complications	0.07%	4.36%	0.05%	< 0.001 †	32.4	14.7-71.5	< **0.001** †
Pneumonia	0.59%	35.9%	0.39%	< 0.001 †	68.8	50.7-93.2	< **0.001** †
Unplanned return to operating room	1.45%	43.6%	1.21%	< 0.001 †	40.1	30.9-52.0	< **0.001** †
Deep vein thrombosis	0.25%	5.37%	0.22%	< 0.001 †	13.20	7.3-23.8	**0.011** †
Stroke/cerebrovascular accident	0.07%	3.02%	0.05%	< 0.001 †	26.7	11.2-63.9	< **0.001** †
Sepsis	0.20%	14.8%	0.16%	< 0.001 †	15.8	9.0-27.7	< **0.001** †
Wound infection	0.40%	2.01%	0.39%	< 0.001 †	4.7	2.0-11.0	< **0.001** †
Wound dehiscence	0.04%	0.00%	0.04%	0.729	–	–	–
Urinary tract infection	0.50%	6.71%	0.46%	< 0.001 †	7.1	4.2-11.8	< **0.001** †
Perioperative blood transfusion	0.30%	11.1%	0.24%	< 0.001 †	18.5	11.7-29.3	< **0.001** †
Unplanned readmission	3.55%	26.7%	3.42%	< 0.001 †	5.4	4.1-7.3	< **0.001** †
Non-home discharge	4.40%	45.6%	4.16%	< 0.001 †	8.5	6.4-11.1	< **0.001** †

† Significance defined as $p < 0.05$, significant values are in bold.
OR: Odds ratio; CI: Confidence interval

who were extubated <48 hours after surgery also required unplanned re-intubation.

Postoperative Complications

Patients who developed RC after ACSS had significantly higher rates of total complications (75.8%) relative to those who did not (2.66%) (Table 2). On multivariate, all assessed comparisons of postoperative outcomes, with the exception of wound dehiscence, remained significantly higher in the RC relative to the non-RC cohort. The most common complications were unplanned return to the operating room (43.6%, Odds ratio [OR] 40.1, 95% confidence interval [CI] 30.9-52.0), pneumonia (35.9%, OR 68.8, 95%CI 50.7-93.2), sepsis (14.8%, OR 15.8, 95%CI 9.0-27.7), and death (11.7%, OR 51.5, 95%CI 30.6-86.9). Additionally, patients who developed RC had higher rates of perioperative blood transfusions (11.1%, OR 18.5, 95% CI 11.7-29.3), unplanned hospital readmission (26.7%, OR 5.4, 95%CI 4.1-7.3), and non-home discharge (45.6%, OR 8.5, 95%CI 6.4-11.1; $P < 0.001$ for all comparisons unless otherwise noted).

Of the 130 reoperations that occurred in the RC cohort, 52 (40.0%) were for hematoma evacuation and 18 (13.8%) were for tracheostomy (Table 3). Of the 69 RC patients who required readmission, 26 (37.7%) were for respiratory complications (including pneumonia, tracheostomy complications, and respiratory failure) and 13 (18.8%) were hematoma related.

Table 3. Reasons for Reoperation and Readmission in Patients With Respiratory Compromise.

Reoperation reason	Number (% of total)
Hematoma evacuation	52 (40.0%)
Tracheostomy	18 (13.8%)
Revision procedure (repeat arthrodesis, decompression)	14 (10.8%)
Unrelated to cervical spine	10 (7.7%)
Infectious (abscess, soft tissue debridement)	5 (3.8%)
Wound dehiscence	3 (2.3%)
Reason for reoperation unknown	28 (21.5%)
Total reoperations	130 (100.0%)
Readmission reason	**Number (% of total)**
Respiratory (pneumonia, tracheostomy complication, respiratory failure)	26 (37.7%)
Hematoma	13 (18.8%)
Unrelated to cervical spine	8 (11.6%)
Non-surgical site infection (sepsis, *Clostridium difficile*)	6 (8.7%)
Recurrence of neck pain or myelopathic symptoms	4 (5.8%)
Surgical site infection	4 (5.8%)
Dysphagia	4 (5.8%)
Hardware failure	1 (1.4%)
Reason for readmission unknown	3 (4.3%)
Total readmissions	69 (100.0%)

Independent Predictors of RC

On multivariate analysis, patient age 61 to 70 (OR 2.3, 95%CI 2.5-6.1), age >70 (OR 3.9, 95%CI 2.5-6.1), non-white ethnicity (OR 1.4, 95%CI 1.1-1.8, $P = 0.011$), medical comorbidities including hypertension (OR 1.4, 95%CI 1.1-1.9, $P = 0.018$), smoking history (OR 1.4, 95% 1.1-1.9, $P = 0.009$), diabetes mellitus (OR 1.4, 95%CI 1.1-1.8, $P = 0.009$), COPD

Table 4. Independent Predictors of Postoperative Respiratory Complications.

	OR	95% CI	*P*-value
Age			
< 50	Reference	-	-
51-60	1.7	1.1-2.5	**0.011** †
61-70	2.3	1.5-3.5	< **0.001** †
> 70	3.9	2.5-6.1	< **0.001** †
Male gender	1.7	1.3-2.2	< **0.001** †
Ethnicity			
White	Reference	-	-
Black	0.6	0.2-1.8	0.345
Other or not reported	1.4	1.1-1.8	**0.011** †
Body mass index *(kg/m^2)*			
Non-obese (< 30)	Reference	-	-
Obese I (30-34.9)	0.7	0.5-1.1	0.053
Obese II (35-39.9)	0.9	0.6-1.3	0.581
Obese III (> 40)	1.2	0.8-1.8	0.350
Comorbidities			
Hypertension	1.4	1.1-1.9	**0.018** †
Smoking history	1.4	1.1-1.9	**0.009** †
Diabetes mellitus	1.4	1.1-1.8	**0.009** †
Dyspnea	1.4	0.9-2.0	0.108
COPD	1.6	1.2-2.4	**0.007** †
Bleeding disorder	1.8	1.0-3.2	0.058
Congestive heart failure	3.0	1.2-7.3	**0.019** †
Dependent functional status	4.4	3.1-6.2	< **0.001** †
Preoperative myelopathy	1.3	1.1-1.7	**0.018** †
Operative duration *(hours)*			
< 2	Reference	-	-
2-3	1.3	1.0-1.8	0.059
> 3	2.3	1.7-3.1	< **0.001** †
Procedure			
ACDF (# of levels)			
One	Reference	-	-
Two	0.9	0.7-1.3	0.738
Three or more	1.2	0.8-1.9	0.370
ACCF (# of levels)			
One	1.5	1.0-2.5	0.068
Two or more	2.3	1.5-3.6	< **0.001** †
CDA	1.1	0.3-1.9	0.463
Ambulatory surgery	0.5	0.2-1.1	0.070
ASA classification			
I or II	Reference	-	-
III or IV	1.9	1.4-2.5	< **0.001** †

† Significance defined as $p < 0.05$, significant values are in bold.
COPD: Chronic Obstructive Pulmonary Disease, ASA: American Society of Anesthesiologists; ACDF: Anterior cervical discectomy and fusion; ACCF: Anterior cervical corpectomy and fusion; CDA: Cervical disc arthroplasty.

(OR1.6, 95%CI 1.2-2.4, $P = 0.007$), congestive heart failure (OR 3.0, 95%CI 3.1-6.2, $P = 0.019$), and dependent functional status (OR 4.4, 95%CI 3.1-6.2) were independent predictors of developing RC (Table 4). Operative factors that were predictive of RC included preoperative myelopathy (OR 1.3, 95%CI 1.1-1.7, $P = 0.018$), operative duration >3 hours (OR 2.3, 95%CI 1.7-3.1), 2-level ACCF (OR 2.3, 95%CI 1.5-3.6), and ASA classification III or IV (OR 1.9, 95%CI 1.4-2.5; $P < 0.001$ for all comparisons unless otherwise noted).

Discussion

This study identified 298 patients who developed RC, which occurred in 0.57% of all anterior cervical spine surgeries. Patients who develop RC have extremely high 30-day mortality (11.7%) and morbidity (75.8%) including pneumonia, return to the operating room, among others. We established a variety of patient-specific and operative predictors of developing RC after ACS, including increasing patient age, a history of preoperative cardiac or pulmonary comorbidities, dependent functional status, preoperative myelopathy, 2-level ACCF procedures, and prolonged operative duration. This is one of the largest RC cohorts described to date in the literature that identified the most comprehensive independent predictors of RC. These findings are useful for patient counseling, risk stratification, and surgical co-management in conjunction with the anesthesiology team for patients who are undergoing ACSS.

Given the low incidence of RC after ACSS, Marquez-Lara et al. was the first to leverage a large, national registry, the National Inpatient Sample (NIS), to query patients undergoing ACDF between 2002-11.[24] In total, the authors identified 1,464 cases of RC, which they defined as unplanned reintubations, with a total incidence of 0.56%. This incidence is concordant with the findings from our study; however, it does not include patients who had prolonged postoperative intubation. The authors identified age $\geq$ 65, 3-level or more ACDF, medical comorbidities such as congestive heart failure, chronic lung disease, neurological disorders, paralysis as predictors of RC in their cohort. This current study identified similar predictors of RC (with the exception of variables not available in the ACS-NSQIP such as neurological disorders), in addition to identifying relevant and potentially modifiable operative characteristics not described by Marquez-Lara et al., including preoperative myelopathy, operative duration, multi-level corpectomies, and ASA classification. Furthermore, the NIS is limited to outcomes only through the inpatient stay, and does not track patients after discharge which is a weakness relative to the ACS-NSQIP. To date, only small case studies discussed an association between myelopathy and RC, with conflicting results.[8,14] It is possible that prior studies have been too underpowered to identify an association between myelopathy and RC, as patients with cervical myelopathy have been shown previously to have abnormal spirometry findings with decreased vital capacity, peak expiratory flow rate, increased respiratory rate,[25,26] and with one case report even identifying myelopathy as a cause of bilateral phrenic nerve palsies.[27]

Prior studies have utilized the ACS-NSQIP to identify the incidence and predictors of RC. Lim et al. in 2017 also utilized this registry to identify patients between 2011-2013 who underwent single- or multi-level (defined as two or more) ACDF.[28] In total they identified 73 patients who developed RC (total incidence of 0.60%), with independent predictors including increasing patient age, male gender, respiratory comorbidities, higher ASA class, and operative duration. The authors did not assess for the association between preoperative myelopathy and RC, and also did not find corpectomy as a predictor of

RC. This is in contrast to our current study which identified a 2-level ACCF as having 2.3-fold higher odds of developing RC, relative to a one-level ACDF. This discrepancy may be due to the fact that the Lim et al. study had significantly fewer RC patients than this current study, or because they grouped all corpectomies together and did not sub-stratify by the number of corpectomies that were performed.[28] Of note, our current study also did not find an increased risk of RC with a single-level corpectomy. One prior case report did note an association between multi-level corpectomies and upper airway obstruction requiring reintubation, however, it was not sufficiently powered to perform a formal statistical analysis.[8] Corpectomies are typically reserved for cases that require substantial decompression, often in the setting of myelopathy.[29,30] The increased rates of RC in our 2-level corpectomy cohort may have been due to an increased rate of preoperative myelopathy in this cohort, which impacts respiratory function. Additionally, the exposure for a corpectomy is typically more extensive than that of an ACDF or CDA in order to adequately visualize the lateral wall of the vertebral body to ensure adequate and complete decompression has occurred. Prior studies have demonstrated increased pre-vertebral soft tissue swelling as a function of number of levels fused, corpectomies, and upper cervical spine surgery.[31,32]

While previous studies have identified the incidence and risk factors for RC,[24,28,33] none have fully defined the short-term clinical course of patients who develop RC. This study demonstrates that patients who develop RC have high rates of both morbidity and mortality. The high morbidity in this study (75.8%) is primarily driven by high rates of unplanned reoperations (43.6%) within 30-days of index surgery—most commonly for hematoma evacuation, presumably the etiology of RC in these patients, and for tracheostomy, illustrating the dismal prognosis for many patients who develop RC. A compressive hematoma may be the most common etiology of RC, reported between 0.6% and 1.3% in ACSS,[34,35] and may be due to vascular injury, inadequate hemostasis, or for unknown etiologies.[36,37] Interestingly, we did not find a statistical association between preoperative bleeding disorders and the development of RC. A case study by Song et al. corroborates this association as they had 9 patients develop compressive hematomas with respiratory symptoms at an average of 33 hours after index ACSS, however, none had preoperative coagulopathy.[38] In 3 patients who underwent hematoma evacuation in that case report, the sources of bleeding were identified as the jugular vein, an intramuscular vessel, and the superior thyroid artery.

This study has a number of limitations that are primarily inherent to national registry outcomes-based analyses. First, we were only able to identify short-term, 30-day outcomes and are unable to elucidate the medium- and long-term clinical courses, such as morbidity, mortality, and instrumentation failure, in patients who develop RC. Next, we identified myelopathy as an independent predictor of developing subsequent RC, however, we were not able to assess the relationship between the severity of myelopathy and the development of RC. Our classification of preoperative myelopathy was also predicated on postoperative ICD coding, which may be prone to misclassification or error. Additionally, drain utilization postoperatively may impact the development of compressive hematomas which may be a cause of RC. Unfortunately, we are unable to identify drain utilization information including number and type of drains used, duration of utilization, and drain output volume. Finally, we lacked a number of relevant variables that may have proven to be independent predictors of RC, such as preoperative anti-coagulant consumption, history of anesthetic related complications, utilization of steroid preparations during surgery to reduce swelling, among others.

In spite of these limitations, this current study identified one of the largest cohorts of patients to develop RC after ACSS and identified a range of independent predictors, some of which have only been previously described in case reports. RC is an extremely rare complication after ACSS with significant short-term morbidity and mortality. High risk patients, such as elderly males with cardiac and pulmonary comorbidities, a history of myelopathy, undergoing a lengthy ACSS procedure such as multi-level ACCF should be counseled on the risk for catastrophic complications such as RC. This data also is useful for preoperative risk stratification and surgical co-management discussions with the anesthesiology team.

Authors' Note

This study utilized national, de-identified data and is exempt from IRB review. This study does not have any prior or duplicate submissions or publications elsewhere of any part of the work. No funding sources, including from the National Institutes of Health; Wellcome Trust; or Howard Hughes Medical Institute, were utilized to complete this study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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Supplemental Material

Supplemental material for this article is available online.

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