

Hybrid Anterior Cervical Discectomy and Fusion and Cervical Disc Arthroplasty: An Analysis of Short-Term Complications, Reoperations, and Readmissions

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Abstract

Study Design: Retrospective cohort study.

Objectives: Although cervical disc arthroplasty (CDA) has become a well-established and effective treatment for symptomatic cervical degeneration, many patients with multilevel disease are not good candidates for CDA at all levels. For such patients, hybrid surgery (HS)—a combination of adjacent anterior cervical discectomy and fusion (ACDF) and CDA—may be more appropriate. Given the novelty of HS and the relative dearth of studies adequately assessing short-term perioperative complications, this current study sought to assess the short-term morbidity profile of HS, differences in operative duration, length of stay (LOS), and readmission and reoperation rates and reasons relative to a 2-level ACDF cohort.

Methods: All patients who underwent HS and 2-level ACDF were identified between 2011 and 2018 using a large, prospectively collected registry. Baseline patient characteristics and postoperative complications were compared using bivariate and/or multivariate analysis.

Results: A total of 390 patients undergoing HS were identified. Two-level procedures were the most common (74.9%). Patients undergoing HS were more likely to be younger, male, and have fewer comorbidities. There were no differences between HS and 2-level ACDF in rates of any postoperative complication, transfusion, readmissions, and operative duration. However, HS had a decreased LOS (0.5 days), relative to a 2-level ACDF. HS patients had low rates of reoperation (1.28%) with 1 case for hematoma evacuation and another for revision CDA.

Conclusions: This study represents one of the largest cohorts of patients undergoing HS reported to date. Patients undergoing HS are not at increased risk of perioperative complications relative to a 2-level ACDF and may benefit from shorter LOS.

Keywords

hybrid surgery, cervical spine, anterior cervical discectomy and fusion, ACDF, cervical disc arthroplasty, CDA, complications, outcomes

Introduction

Anterior cervical discectomy and fusion (ACDF) and cervical disc arthroplasty (CDA) are effective procedures for cervical spondylosis in patients with or without myelopathy. Numerous head-to-head studies have compared the short- and long-term outcomes for single-level disease.¹⁻⁵ Single-level ACDF and CDA have similar adjacent-segment operations at 1-year follow-up (3.6% and 2.3%, respectively); however, at 7-year

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follow-up, the reoperation rates are significantly lower in patients with an index CDA (12.7% vs 5.2%, respectively).^{1,2} Both procedures have low perioperative morbidity, with studies demonstrating improvements in postoperative range of motion in CDA patients, relative to ACDF.³ In the context of multilevel spondylosis, multilevel ACDF remains the gold standard; however, there remains concerns regarding motion preservation and the need for multilevel fusion. As a result, multilevel CDAs have been performed. In comparison with multilevel ACDF, these patients may have lower rates of adjacent-segment disease and reoperation with a similar perioperative complication profile.⁶

While CDA may have some advantages over ACDF, it is contraindicated in patients with rheumatological disease, severe spondylotic changes, nonmobile segments that are essentially auto-fused, significant posterior facet arthrosis, poor bone density, among others.^{7,8} Recognizing that every pathological cervical spine segment has its own unique characteristics and that in a given patient, ACDF may be appropriate at one level whereas CDA may be better indicated at an adjacent level, Barbagallo et al⁹ in 2009 were among the first to publish on a series of patients undergoing hybrid surgery (HS) of the cervical spine. The authors' hybrid constructs consisted of ACDF (with a mixture of cage and plate utilization) and CDA in 24 patients with cervical spondylosis with anterior neural compression leading to radiculopathy, and with concurrent myelopathy in 14 patients. Fifteen patients underwent a 2-level, 7 patients a 3-level, and 2 patients a 4-level HS. At a mean of 23.8-month follow up, there was a significant improvement in functional scores among all patients, in patients with myelopathy a majority had improvement in myelopathic symptoms, and only 1 complications were noted—heterotopic ossification.

Since the publication of this initial report on HS,⁹ various other groups have described their experiences with HS, often in comparison with an ACDF cohort in patients with multilevel spondylosis. For instance, a meta-analysis by Zhang et al¹⁰ in 2020 identified seven studies with head-to-head HS and ACDF comparisons and found that HS had more significant improvements in neck disability scores and range of motion, relative to ACDF at 2-year follow-up. However, 5 of these studies were retrospective, only 109 HS patients were assessed, and short-term perioperative complications were not discussed.

Given the novelty of HS and the relative dearth of studies adequately assessing short-term perioperative complications, this current study sought to assess the short-term morbidity profile of HS, differences in operative duration, length of stay (LOS), and readmission and reoperation rates and reasons relative to a 2-level ACDF cohort.

Methods and Materials

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 and 2018. There were over 1 million unique surgical cases

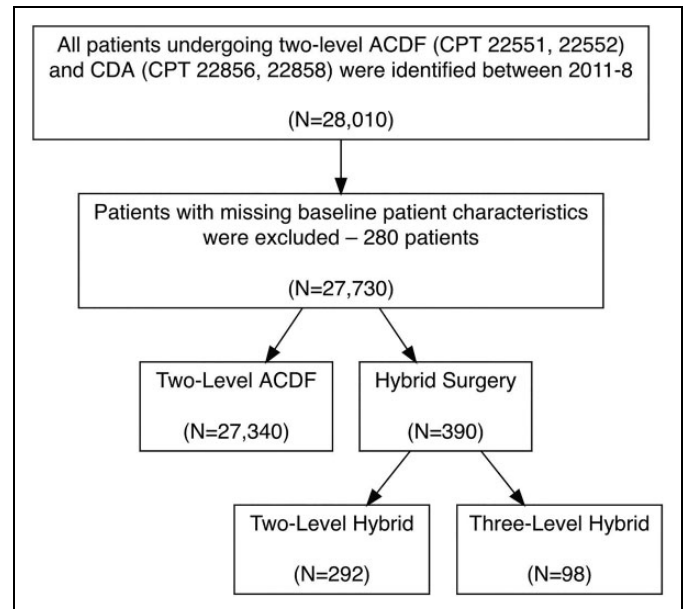


Figure 1. STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) diagram of included patients. ACDF, anterior cervical discectomy and fusion; CDA, cervical disc arthroplasty; CPT, Current Procedural Terminology.

collected in this registry from over 700 clinical centers and consisting of over 250 variables.¹¹ These clinical sites range from large academic centers to smaller community hospitals. At participating institutions, procedures are randomly selected for inclusion in the ACS-NSQIP. Patients who are included 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 interrater reliability,¹²⁻¹⁴ and has been used extensively in orthopedics outcomes-based research.¹⁵⁻¹⁸

Patient Identification

All patients who underwent 2-level ACDF or HS were identified using Current Procedural Terminology (CPT codes). Patients undergoing 2-level ACDF were defined as having a CPT code of 22 551 in conjunction with CPT code 22 552 during the same operative procedure. Those who underwent 2-level HS were defined as having CPT 22 551 in conjunction with 22 856, and 3-level HS had combinations of CPT 22 551, 22 552, 22 856, and 22 858. (Supplemental Appendix I) Patients with missing baseline patient-specific or operative characteristics were excluded (Figure 1).

Preoperative Characteristics and Postoperative Outcomes

Baseline characteristics were identified for each patient. These characteristics included patient age, gender, ethnicity (White, Black, other), body mass index (BMI, calculated from patient

Table 1. Comparison of Patient Characteristics by Procedure Type.

	Two-level ACDF, %	Hybrid surgery, %	<i>P</i> ^a
No. of patients	27 340	390	
Age (years)			<.001
<50	30.8	55.1	
51-60	34.7	31.0	
61-70	24.1	11.8	
>70	10.3	2.1	
Female	50.5	45.1	.036
Ethnicity			.074
White	80.9	80.0	
Black	1.6	3.1	
Other or not reported	17.5	16.9	
Body mass index (kg/m ²)			.312
Nonobese (<30)	53.2	56.7	
Obese I (30-34.9)	26.1	26.2	
Obese II (35-39.9)	12.7	11.3	
Obese III (>40)	8.0	5.9	
Comorbidities			
Hypertension	48.6	30.0	<.001
Smoking history	27.1	28.2	.632
Diabetes mellitus	16.9	10.0	<.001
Dyspnea	5.6	4.9	.552
COPD	4.9	3.8	.354
Preoperative corticosteroid use	3.4	2.6	.372
Bleeding disorder	1.2	0.8	.320
Dependent functional status	1.6	2.1	.529
ASA classification			<.001
I	2.8	5.9	
II	50.9	65.1	
III or IV	46.2	29.0	

Abbreviations: COPD, chronic obstructive pulmonary disease; ASA, American Society of Anesthesiologists; ACDF, anterior cervical discectomy and fusion.

^aSignificance defined as $P < .05$, significant values are in boldface.

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 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 nonhome discharge. Readmission and reoperation reasons were identified using International Classification of Disease and CPT codes, respectively. Operative duration and total hospital LOS were continuous variables that were also recorded for all included patients.

Statistical Analysis

Statistical analysis was performed using SPSS version 25 (IBM Corp) and R version 3.6.3 (R Core Team, 2020).¹⁹ Baseline

Table 2. Comparison of 30-Day Complications by Procedure Type.^a

	Two-level ACDF (n = 27 340), %	Hybrid surgery (n = 390), %	Bivariate analysis <i>P</i> ^b
Any complication	3.61	2.56	.271
Death	0.31	0.00	.267
Cardiac complications	0.28	0.00	.297
Renal complications	0.09	0.00	.558
Pulmonary complications	0.86	0.00	.066
Deep vein thrombosis	0.31	0.26	.848
Stroke/cerebrovascular accident	0.14	0.00	.461
Return to operating room	1.76	1.28	.476
Sepsis	0.27	0.26	.957
Wound infection	0.40	0.77	.259
Wound dehiscence	0.07	0.00	.593
Urinary tract infection	0.51	0.26	.486
Perioperative blood transfusion	0.64	0.00	.112
Unplanned readmission	3.68	3.56	.538
Nonhome discharge ^c	7.12	2.59	.002

Abbreviation: ACDF, anterior cervical discectomy and fusion.

^aA total of 21 813 patients in the ACDF cohort had readmission data (79.8% of total), and 309 patients in the hybrid surgery cohort had readmission data (79.2%).

^bSignificance defined as $P < .05$, significant values are in boldface.

^cOn multivariate analysis, hybrid surgery did not have differing rates of non-home discharge (odds ratio 1.2, 95% CI 0.6-2.2, $P = .608$).

patient-specific/operative characteristics and postoperative complications were compared using bivariate analysis. Any baseline patient-specific/operative characteristic with $P < .200$ was adjusted for in a multivariate analysis. Binary logistic multivariate models were used to compare postoperative complications. Statistical significance was defined as $P < .050$.

Results

In total, there was 390 patients who underwent HS and 27 340 patients who underwent 2-level ACDF (Table 1). A total of 292 patients in the HS underwent a 2-level procedure (74.9%), whereas 98 underwent a 3-level or more HS (25.1%). Between 2011 and 2018, the proportion of HS to ACDF procedures ranged between 1.2% and 1.6%. Patients who underwent HS were younger, male ($P = .036$), less likely to have a history of hypertension and diabetes mellitus, and had a lower ASA classification ($P < .001$ for all comparisons, unless otherwise noted).

Postoperative Complications

There was no significant difference between total complication rates between 2-level ACDF (3.61%) and HS (2.56%, $P = .271$) (Table 2). The most common complications after HS were surgical site infection (0.77%), urinary tract infection, DVT, and sepsis (0.26% for all). On bivariate analysis, the rate of nonhome discharge in patients undergoing HS (2.59%) was

Table 3. Association of Procedure Type With Operative Duration and Postoperative Length of Stay.

	Two-Level ACDF				Hybrid				Beta ^a	P
	Mean	Median	SD	SEM	Mean	Median	SD	SEM		
Operative duration (minutes)	149	133	75	0.5	145	133	66	3.4	-1.0	.758
Length of stay (days)	2.1	1.0	2.4	0.1	1.2	1.0	1.2	0.1	-0.5	<.001

Abbreviation: ACDF, anterior cervical discectomy and fusion; SEM, standard error margin.

^aUnstandardized beta from multivariate linear regression; represents unit change in operation time (minutes) or length of stay (days).

lower than ACDF (7.12%, $P = .002$). However, on multivariate analysis adjusting for differences in baseline patient characteristics, HS did not have a significantly decreased rate of non-home discharge (odds ratio 1.2, 95% CI 0.6-2.2, $P = .608$).

The mean operative duration for a 2-level ACDF was 149 minutes (SD 75, median 133, standard error margin [SEM] 0.5), and was 145 minutes (SD 66, median 133, SEM 3.4) for HS, which was not significantly different on multivariate linear regression ($P = .758$) (Table 3). However, total LOS was significantly decreased by 0.5 days ($P < .001$) in the HS cohort (mean 1.2, SD 1.2, median 1.0, SEM 0.1 days) relative to the 2-level ACDF cohort (mean 2.1, SD 2.4, median 1.0, SEM 0.1 days) on multivariate analysis.

Reoperation and Readmission Reasons

The total 30-day reoperation rate for HS was 1.28% (5 revision cases) for removal of foreign body (2 cases, 40.0%), hematoma evacuation (1 case, 20.0%), revision cervical disc arthroplasty (1 case, 20.0%), carpal tunnel release (1 case, 20.0%) (Table 4). A total of 79.2% of the HS cohort had readmission data available (309 patients), with a total readmission rate of 3.56% (11 patients). The most common reasons for readmission were for medical reasons (5 patients, 45.5%), postoperative pain or recurrence of radiculopathy/myelopathy (2 patients, 18.2%), hematoma evacuation (1 patient, 9.1%), and hardware failure (1 patient, 9.1%).

Discussion

HS of the cervical spine is a powerful surgical tool in the treatment of cervical spondylosis that tailors a surgical plan to each patient's unique pathology, and with early studies demonstrating low long-term complications, and improvements in postoperative range of motion and functional scores (Figure 2). The current study identified a similar short-term complication profile and operative duration to that of a 2-level ACDF; however, patients undergoing HS may benefit from shorter LOS. A majority of the patients in this cohort underwent two-level HS (74.9%), had a low reoperation rate, and low readmission rates with the most common reason being nonsurgical-related medical problems. This study utilized a large, national, prospectively collected registry to identify one of the largest cohorts of HS patients reported to date.

No difference in total 30-day complication rates between HS (2.56%) and 2-level ACDF (3.61%) cohorts was identified.

Table 4. Reasons for Reoperation and Readmission After 2-Level ACDF and Hybrid Procedures

	Two-level ACDF, n (%)	Hybrid surgery, n (%)
Reoperation reason		
Revision procedure (removal of hardware, anterior or posterior decompression, arthrodesis)	117 (24.3)	1 (20.0)
Vascular related (hematoma drainage, embolectomy, vessel graft/repair)	89 (18.5)	1 (20.0)
Infectious (abscess, bone/muscle debridement)	82 (17.0)	0 (0.0)
Upper respiratory (laryngoscopy, bronchoscopy, tracheostomy)	40 (8.3)	0 (0.0)
Unrelated to cervical spine	39 (8.1)	1 (20.0)
CSF related (dural tear, CSF drainage, or shunt creation)	17 (3.5)	0 (0.0)
Wound complications (dehiscence, flap coverage)	12 (2.5)	0 (0.0)
Removal of foreign body	2 (0.04)	2 (40.0)
Reason for reoperation unknown	83 (17.3)	0 (0.0)
Total reoperations	481 (100.0)	5 (100.0)
Readmission reason		
Nonrespiratory medical complications (eg, stroke, seizure)	386 (41.4)	5 (45.5)
Respiratory complications (pneumonia, respiratory failure)	106 (11.4)	0 (0.0)
Hematoma or seroma	90 (9.7)	1 (9.1)
Postoperative pain, recurrence of radiculopathy or myelopathy	86 (9.2)	2 (18.2)
Dysphagia	80 (8.6)	1 (9.1)
Surgical site infection or wound dehiscence	65 (7.0)	0 (0.0)
Orthopedic issue unrelated to cervical spine	18 (1.9)	0 (0.0)
Hardware complication	16 (1.7)	1 (9.1)
Reason for readmission unknown	85 (9.1)	1 (9.1)
Total readmissions	932 (100.0)	11 (100.0)

Abbreviations: ACDF, anterior cervical discectomy and fusion; CSF, cerebrospinal fluid.

This is in concordance with prior reported literature. For instance, Liu et al²⁰ reported on 199 patients with cervical spondylotic myelopathy undergoing multilevel ACDF (103 patients) or a hybrid construct (96 patients). The authors identified a total complication rate of 15.5% in the ACDF cohort and 22.9% in the hybrid cohort, with the most common



Figure 2. Sample hybrid construct radiographs of cervical disc arthroplasty adjacent to single- or multilevel cervical discectomy or corpectomy and fusions.

complications among hybrids being dysphagia, hoarseness, and C5 nerve palsy. The authors did not perform a formal statistical analysis comparing these rates, however, noted that qualitatively that there was no significant difference in complication rates between cohorts. While the Liu et al²⁰ study and our current study identified no major differences in complication rates between similar cohorts, their rates of complications were higher likely due to (1) longer follow-up time of 3.6 years and (2) analysis of different outcome and complication variables. In our study, one of the most common complications, although not significantly different from ACDF, was a superficial or deep surgical site infection at 0.77% in the hybrid cohort. This is in agreement with prior studies that have reported infection rates between 1.0% and 1.4%,^{20,21} and also with a recent meta-analysis that did not find significant differences in surgical site infection between multi-level ACDF and hybrid patients.²²

This study did not identify any significant difference in operative duration between the ACDF and hybrid cohorts but did find a half-day decrease in LOS in the hybrid cohort on multivariate analysis that adjusted for differences in baseline patient characteristics. This is in concordance with a retrospective cohort study of 14 patients undergoing multilevel ACDF (7 patients) and HS (7 patients) by Hey et al.²³ The authors here

noted a mean operative duration of 135 minutes in the ACDF cohort (vs 149 in this study) and 195 minutes in the hybrid cohort (vs 145 in this study), which they found to be not statistically different.²³ The statistical analysis in this study was a bivariate analysis that did not account for preoperative baseline differences. The authors also found a significantly shorter LOS in the hybrid relative to ACDF cohort, which is in agreement with the results presented in this study. However, other studies have not corroborated similar findings with regards to decreased length of stay after HS.²⁴ Many prior studies comparing ACDF and CDA have found a decrease in total LOS in CDA patients.^{5,25,26} While the exact reason for this remains unclear, it may be that CDA patients tend to be younger with fewer medical comorbidities.^{5,26} Interestingly, in our current study we similarly found that patients undergoing HS were significantly younger and had lower rates of hypertension and diabetes mellitus, relative to the ACDF cohort.

Notable reasons for 30-day reoperation, which occurred in 1.28% of all HS patients, included 1 instance of hematoma decompression and 1 instance of a revision CDA. No prior studies have reported on a compressive hematoma requiring evacuation in an ACDF/CDA HS; however, it has been reported with various other hybrid procedures such as

combined ACDF/ACCF (anterior cervical corpectomy and fusion).²⁷ The occurrence of a hematoma in our HS cohort is not unexpected as this is a known complication after anterior cervical spine surgery. Prior studies have identified postoperative hematoma to be between 0.6% and 1.3%.^{28,29} However, increasing patient age as well as preoperative cardiac and pulmonary comorbidities are known risk factors for compressive hematoma and respiratory compromise after anterior cervical spine surgery. Given that HS patients tend to be younger and healthier, this may ultimately lead to a lower rate of this potentially catastrophic complication.^{30,31} Finally, there are limited studies assessing long-term implant survivorship and reoperation rates in patients undergoing HS. One notable study is by Zigler et al,³² who reported on 115 hybrid procedures at a mean follow-up duration of 6.5 years (including nonhybrid patients) and identified 6 patients who required reoperation. Five patients in this series underwent reoperation for adjacent segment disease and 1 for pseudarthrosis at the level of the ACDF in the hybrid construct. However, besides the single patient in this current study who underwent revision CDA, there have not been any prior reports on revision CDA in a hybrid construct within 30 days of the index procedure.

This study has numerous limitations which are primary intrinsic to the utilization of large, national registries. First, our analysis is limited to 30 days from the index HS, and therefore we are unable to assess medium- or long-term complications such as pseudarthrosis. Furthermore, we lacked variables that may be particularly relevant to HS, including pre- and postoperative symptoms, range of motion, functional scores such as the Neck Disability Index, radiographic outcomes, and which specific spinal levels were operated on as constructs at different locations may lead to different biomechanical implications.³³ Next, we were only able to identify patients who underwent ACDF and CDA during the same index procedure, and cannot identify if contiguous levels were operated on. Patients may also have undergone a staged hybrid surgery that occurred more than 30 days apart, in which case we would have been unable to identify this. However, it is reassuring that in many reported clinical studies HS occurred in a simultaneous fashion.²³ Finally, patients who had an initial CDA or ACDF may undergo reoperation for adjacent segment disease with an additional CDA or ACDF at a later time point. These patients would functionally have a hybrid construct; however, we would not have been able to identify these patients with the methodology employed.

Despite these limitations, this current study represents one of the largest cohorts of patients undergoing HS reported to date. Patients undergoing HS are not at increased risk of perioperative complications relative to a 2-level ACDF, and may benefit from shorter length of stay. Reoperations within 30 days are rare; however, we do report 1 incidence of hematoma evacuation and another of revision CDA.



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Supplemental Material

Supplemental material for this article is available online.

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