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Single-level cervical disc replacement (CDR) versus anterior cervical discectomy and fusion (ACDF): A Nationwide matched analysis of complications, 30- and 90-day readmission rates, and cost

Ravi S. Nunna[a,*], James S. Ryoo[b], Philip B. Ostrov[b], Saavan Patel[c], Periklis Godolias[d], Zeyad Daher[d,e], Richard Price[d], Jens R. Chapman[d], Rod J. Oskouian[d]

[a] *Department of Neurosurgery, University of Missouri Columbia Health Care, Columbia, MO, USA*
[b] *University of Illinois at Chicago College of Medicine, Chicago, IL, USA*
[c] *Department of Neurosurgery, University of Illinois at Chicago, Chicago, IL, USA*
[d] *Swedish Neuroscience Institute, Seattle, WA, USA*
[e] *Dornsife College of Letters, Arts and Sciences, University of Southern California, Los Angeles, CA, USA*

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1. Introduction

Cervical disc replacement (CDR) is a recently emerging alternative to anterior cervical discectomy and fusion (ACDF) for symptomatic cervical spondylosis. First described in the 1960s, CDR was developed with the notion that replacement with an artificial disc after neural decompression could preserve motion of the cervical spine, minimize the biomechanical stress on adjacent levels, and decrease the risk of subsequent adjacent segment disease and reoperation.[1,2] Indeed, several series and mid-term results from randomized-controlled trials have demonstrated that CDR may prove to be an excellent surgical option when careful patient selection and well-trained, meticulous technique are able to be achieved.[3–6] Contrary to these positive findings, however, some studies have shown CDR to result in unexpectedly high rates of heterotopic ossification and loss of mobility, especially in two-level procedures.[7,8] Needless to say, continued identification of patient populations that may benefit most from CDR over ACDF and a comprehensive understanding of the relative risks and benefits of the two procedures are necessary prior to complete adoption of this promising treatment.[9]

Due to the similarities in approach, CDR and ACDF share a similar short-term postoperative complication profile, which includes dysphagia, infection, dural tear, major vessel injury, Horner's syndrome, and recurrent laryngeal nerve injury.[10] While the complication rates for each approach are well-described in the literature, associated outcomes of the index hospital stay, such as cost and length of stay (LOS), and associated readmission rates in the immediate postoperative period have been poorly characterized. Herein, we illustrate a comparison between CDR and ACDF regarding post-operative complications, readmission rates, hospital cost, and length-of-stay while identifying risk factors associated with readmission using a large, central-registry database representative of the U.S. population.

2. Materials and methods

2.1. Database

Admissions data were obtained from the 2015 and 2016 Healthcare

Abbreviations: ACDF, anterior cervical discectomy and fusion; CDR, cervical disc replacement; LOS, length of stay; HCUP, Healthcare Cost and Utilization Project; NRD, National Readmissions Database.

* Corresponding author. Department of Neurosurgery, University of Missouri Columbia Health Care 1 Hospital Dr, Columbia, MO, 65212, USA.
E-mail address: ravisnunna@gmail.com (R.S. Nunna).

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Cost and Utilization Project (HCUP) Nationwide Readmissions Database (NRD). The NRD is a large scale database documenting patient hospitalizations over a calendar year. Data include diagnoses, procedures, and hospital factors.

2.2. Patient sample

15,418 patients undergoing single level ACDF or CDR were identified by ICD-10 procedural codes 0RG10A0 and 0RR30JZ respectively. 13,516 underwent ACDF and 1902 underwent CDR. Exclusion criteria included non-elective cases, patients under 18, death at the end of the index admission, and 2+ level cervical fusions (all ICD-10 0RG2 codes). In addition, cases were excluded if both ACDF and CDR were performed at the same index admission. Cases were included from the last quarter of 2015 to the end of 2016. Only the last quarter of 2015 was used because of the transition to ICD-10 starting in October 2015. We extracted patients from 14,519,781 total admissions from the 2016 NRD and 1,295,810 total admissions from the last quarter of the 2015 NRD.

2.3. Hospitalization data

For each index admission, we obtained baseline hospital, demographic, and comorbidity data. Hospital data included length of stay, billed cost, and discharge disposition. Demographic data were age, sex, and insurance status. The Elixhauser comorbidity index was used to define comorbidities on the basis of ICD 10 code groupings. Complications of clinical interest were also defined using ICD 10 code groupings. Readmissions within 30 and 90 days were calculated from the time of discharge at each index admission. Values of 10 or fewer were omitted as per HCUP reporting requirement.

2.4. Propensity score matching

Propensity score matching was performed to create comparable groups between patients undergoing ACDF and CDR. ACDF patients were matched to CDR patients on the basis of age, sex, cardiac arrythmia, congestive heart failure, chronic pulmonary disease, depression, diabetes and hypertension both with and without complication, hypothyroidism, liver disease, obesity, rheumatoid arthritis/collaged vascular disease, and renal failure. Logistic regression was used to generate propensity scores. Matching was performed using the nearest neighbors algorithm with a caliper of 0.001.

2.5. Statistical analysis

Univariate analyses comparing ACDF and CDR were performed using chi-squared and t-tests for categorical and continuous data respectively. After matching, logistic regression was used to generate odds ratios and 95 % confidence intervals comparing ACDF (reference) and CDR with regards to select complications. In addition, a multivariate regression was performed separately for each matched CDR and ACDF cohort to assess risk factors associated with 90 day readmission. Covariates included clinically significant comorbidities and complications with greater than 10 occurrences.

2.6. Software

Analyses were done using Python 3 and its open source statistical software SciPy (1.1.0) and statsmodels (0.11.1). Propensity score matching was performed in R (4.0.2) using the MatchIt (4.0.0) package, and comorbidities were defined using the R Comorbidity package (0.5.3).

3. Results

3.1. Baseline characteristics before propensity score matching

15,418 patients were included for analysis, 1902 (12.3 %) of whom underwent CDR and 13,516 (87.7 %) of whom underwent single-level ACDF. Baseline demographic characteristics and comorbidities prior to propensity score matching are shown in Tables 1 and 2, respectively. CDR patients were significantly younger, with 62.7 % of the cohort under 50 years old. CDR patients were significantly more likely to have private insurance (65.9 % vs 41.3 %) and less likely to have Medicare (10.9 % vs 35.6 %) compared with ACDF patients. A comparison of baseline comorbidities between the two cohorts showed that CDR patients were generally healthier. A significantly smaller proportion of CDR patients had comorbidities such as carotid artery disease, congestive heart failure, chronic pulmonary disease, depression, diabetes, hypertension, hypothyroidism, obesity, renal failure, and rheumatoid arthritis, among others.

3.2. Baseline characteristics after propensity score matching

According to the 1:1 propensity score matching performed in this analysis, 1844 patients were matched in the CDR and ACDF cohorts (Table 3). Matching eliminated significant differences that existed between the two cohorts regarding age and most all comorbidities (Table 4). However, payer status and comorbidities such as drug abuse, psychoses, and weight loss remained significantly different.

Table 1
Baseline characteristics of unmatched CDR versus ACDF cohorts.

Characteristics	Total	CDR	ACDF	p
Age, n (%)				**<0.001**
18–49 years, n (%)	5770 (37.4)	1193 (62.7)	4577 (33.9)	
50–59 years, n (%)	4590 (29.8)	499 (26.2)	4091 (30.3)	
60–69 years, n (%)	3271 (21.2)	181 (9.5)	3090 (22.9)	
70–79 years, n (%)	1499 (9.7)	29 (1.5)	1470 (10.9)	
80 + years, n (%)	288 (1.9)	[a]	288 (2.1)	
Sex				0.238
Male, n (%)	7356 (47.7)	932 (49)	6424 (47.5)	
Female, n (%)	8062 (52.3)	970 (51)	7092 (52.5)	
Payer Status				**<0.001**
Medicaid, n (%)	1557 (10.1)	142 (7.5)	1415 (10.5)	
Medicare, n (%)	5016 (32.5)	207 (10.9)	4809 (35.6)	
Private Insurance, n (%)	6840 (44.4)	1254 (65.9)	5586 (41.3)	
Self-Pay, n (%)	180 (1.2)	29 (1.5)	151 (1.1)	
Other/Unknown, n (%)	1809 (11.7)	269 (14.1)	1540 (11.4)	
No Charge, n (%)	16 (0.1)	[a]	15 (0.1)	
Discharge Disposition				**<0.001**
Routine, n (%)	14,044 (91.1)	1816 (95.5)	12,228 (90.5)	
Home Health Care, n (%)	1035 (6.7)	80 (4.2)	955 (7.1)	
Transfer to Skilled Nursing Facility, n (%)	307 (2.0)	[a]	303 (2.2)	
Transfer to Short-Term Hospital, n (%)	12 (0.1)	[a]	12 (0.1)	
Against Medical Advice, n (%)	20 (0.1)	[a]	18 (0.1)	

[a] Value is below NRD reporting minimum of 10 or fewer cases.

Table 2
Baseline comorbidities of unmatched CDR versus ACDF cohorts.

Comorbidities	CDR	ACDF	p
AIDS/HIV, n (%)	[a]	[a]	0.896
Alcohol Abuse, n (%)	17 (0.9)	142 (1.1)	0.608
Carotid Artery Disease, n (%)	35 (1.8)	571 (4.2)	**<0.001**
Congestive Heart Failure, n (%)	[a]	245 (1.8)	**<0.001**
Coagulopathy, n (%)	11 (0.6)	140 (1.0)	0.076
Chronic Pulmonary Disease, n (%)	231 (12.1)	2322 (17.2)	**<0.001**
Deficiency Anemia, n (%)	[a]	71 (0.5)	0.900
Depression, n (%)	239 (12.6)	2096 (15.5)	**0.001**
Diabetes (complicated), n (%)	28 (1.5)	512 (3.8)	**<0.001**
Diabetes (uncomplicated), n (%)	147 (7.7)	2032 (15.0)	**<0.001**
Drug Abuse, n (%)	27 (1.4)	240 (1.8)	0.307
Fluid and Electrolyte Disorders, n (%)	11 (0.6)	252 (1.9)	**<0.001**
Hypertension (complicated), n (%)	16 (0.8)	368 (2.7)	**<0.001**
Hypertension (uncomplicated), n (%)	474 (24.9)	5708 (42.2)	**<0.001**
Hypothyroidism, n (%)	121 (6.4)	1345 (10.0)	**<0.001**
Liver Disease, n (%)	17 (0.9)	170 (1.3)	0.213
Obesity, n (%)	216 (11.4)	2195 (16.2)	**<0.001**
Other Neurologic Disorder, n (%)	34 (1.8)	399 (3.0)	**0.005**
Paralysis, n (%)	[a]	115 (0.9)	**0.019**
Pulmonary Circulation Disorders, n (%)	[a]	42 (0.3)	0.598
Peripheral Vascular Disorders, n (%)	[a]	238 (1.8)	**<0.001**
Renal Failure, n (%)	17 (0.9)	366 (2.7)	**<0.001**
Rheumatoid Arthritis, n (%)	36 (1.9)	432 (3.2)	**0.002**
Valvular Disease, n (%)	15 (0.8)	221 (1.6)	**0.007**
Elixhauser Comorbidity Index			
Elixhauser Score, mean (SD)	0.91 (1.12)	1.51 (1.45)	**<0.001**

[a] Value is below NRD reporting minimum of 10 or fewer cases.

3.3. Comparison of outcomes between CDR and ACDF

An initial examination of intraoperative and postoperative complications prior to matching showed that CDR patients suffered overall fewer complications. Rates of dural tear, dysphagia, genitourinary complications, postoperative infection, and respiratory complications were significantly lower in the CDR cohort (Table 5). However, these observations were not replicated after propensity score matching, which indicates that the fewer complications in the CDR cohort are perhaps attributable to the lower proportion of patients suffering the comorbidities described in Table 2. In addition, a greater proportion of CDR patients had routine discharges as compared to ACDF patients. This was true both before and after matching.

CDR patients had significantly lower 30-day and 90-day readmission rates compared to ACDF patients: 1.6 % vs 2.2 %; 2.8 % vs 4.0 %, respectively (Table 6), but these differences were not significant after matching. CDR patients had significantly higher cost of inpatient stay compared to ACDF patients with mean differences of $17277.33 and $18,823.75 in pre- and post-matched comparisons respectively. However, CDR patients generally had a shorter length of stay in both unmatched (0.91 days ± 1.12 vs 1.51 days ± 1.45, $p < 0.001$) and matched (1.19 days ± 0.76 vs 1.36 days ± 2.78, $p < 0.014$) analyses. Finally, a matched logistic regression analysis to determine the odds of complications in CDR over ACDF showed that CDR did not have increased odds of any complication (Table 7).

3.4. Multivariate analysis for risk factors associated with 90-day readmission

Table 8 describes the results of a matched multivariate regression analysis to identify risk factors associated with 90-day readmission in both the CDR and ACDF cohorts. Complicated diabetes was significantly associated with an increased odds of readmission in both the CDR (OR 4.80, 97.5 % CI 1.30–17.77, p = 0.019) and ACDF cohorts (OR 4.76, 97.5 % CI 1.29–17.61, p = 0.019). Rheumatoid arthritis was associated

Table 3
Baseline characteristics of matched CDR versus ACDF cohorts.

Characteristics	Total	CDR	ACDF	p
Age, n (%)				0.874
18–49 years, n (%)	2262 (61.3)	1136 (61.6)	1126 (61.1)	
50–59 years, n (%)	999 (27.1)	498 (27.0)	501 (27.2)	
60–69 years, n (%)	365 (9.9)	181 (9.8)	184 (10.0)	
70–79 years, n (%)	61 (1.7)	29 (1.6)	32 (1.7)	
80 + years, n (%)	[a]	[a]	[a]	
Sex				0.843
Male, n (%)	1797 (48.7)	902 (48.9)	895 (48.5)	
Female, n (%)	1891 (51.3)	942 (51.1)	949 (51.5)	
Payer Status				**<0.001**
Medicaid, n (%)	405 (11.0)	137 (7.4)	268 (14.5)	
Medicare, n (%)	533 (14.5)	203 (11.0)	330 (17.9)	
Private Insurance, n (%)	2165 (58.7)	1215 (65.9)	950 (51.5)	
Self-Pay, n (%)	63 (1.7)	29 (1.6)	34 (1.8)	
Other/Unknown, n (%)	518 (14.0)	259 (14.1)	259 (14.1)	
No Charge, n (%)	[a]	[a]	[a]	
Discharge Disposition				**0.003**
Routine, n (%)	3499 (94.9)	1758 (95.3)	1741 (94.4)	
Home Health Care, n (%)	154 (4.2)	80 (4.3)	74 (4.0)	
Transfer to Skilled Nursing Facility, n (%)	26 (0.7)	[a]	22 (1.2)	
Transfer to Short-Term Hospital, n (%)	[a]	[a]	[a]	
Against Medical Advice, n (%)	[a]	[a]	[a]	

[a] Value is below NRD reporting minimum of 10 or fewer cases.

Table 4
Baseline comorbidities of matched CDR versus ACDF cohorts.

Comorbidities	CDR	ACDF	p
AIDS/HIV, n (%)	[a]	[a]	1.00
Alcohol Abuse, n (%)	14 (0.8)	21 (1.1)	0.308
Carotid Artery Disease, n (%)	29 (1.6)	25 (1.4)	0.681
Congestive Heart Failure, n (%)	[a]	[a]	0.627
Coagulopathy, n (%)	[a]	11 (0.6)	0.823
Chronic Pulmonary Disease, n (%)	210 (11.4)	218 (11.8)	0.719
Deficiency Anemia, n (%)	[a]	[a]	0.422
Depression, n (%)	224 (12.1)	227 (12.3)	0.920
Diabetes (complicated), n (%)	25 (1.4)	20 (1.1)	0.549
Diabetes (uncomplicated), n (%)	140 (7.6)	127 (6.9)	0.446
Drug Abuse, n (%)	26 (1.4)	55 (3.0)	**0.002**
Fluid and Electrolyte Disorders, n (%)	11 (0.6)	21 (1.4)	0.110
Hypertension (complicated), n (%)	16 (0.9)	[a]	0.054
Hypertension (uncomplicated), n (%)	458 (24.8)	460 (24.9)	0.970
Hypothyroidism, n (%)	113 (6.1)	107 (5.8)	0.728
Liver Disease, n (%)	16 (0.9)	[a]	0.054
Obesity, n (%)	199 (10.8)	187 (10.1)	0.554
Other Neurologic Disorder, n (%)	34 (1.8)	46 (2.5)	0.214
Paralysis, n (%)	[a]	11 (0.6)	0.210
Pulmonary Circulation Disorders, n (%)	[a]	[a]	1.00
Peripheral Vascular Disorders, n (%)	[a]	16 (0.9)	0.094
Renal Failure, n (%)	16 (0.9)	[a]	0.152
Rheumatoid Arthritis, n (%)	27 (1.5)	20 (1.1)	0.378
Valvular Disease, n (%)	14 (0.8)	[a]	0.403
Elixhauser Comorbidity Index			
Elixhauser Score, mean (SD)	0.88 (1.11)	0.89 (1.08)	0.845

[a] Value is below NRD reporting minimum of 10 or fewer cases.

Table 5
Intraoperative and postoperative complications of unmatched CDR versus ACDF cohorts.

Complications	Before matching			After matching		
	CDR	ACDF	*p*	CDR	ACDF	*p*
Dehiscence, n (%)	20 (1.1)	[a]	1.00	[a]	[a]	1.00
Dural Tear, n (%)	[a]	71 (0.5)	**0.046**	[a]	[a]	0.148
DVT, n (%)	[a]	[a]	0.766	[a]	[a]	1.00
Dysphagia, n (%)	64 (3.4)	599 (4.4)	**0.037**	64 (3.4)	53 (2.9)	0.396
Esophageal Injury, n (%)	[a]	[a]	0.766	[a]	[a]	1.00
GI Complications, n (%)	[a]	23 (0.2)	0.861	[a]	[a]	1.00
GU Complications, n (%)	33 (1.7)	345 (2.6)	**0.038**	32 (1.7)	22 (1.2)	0.217
Hematoma, n (%)	[a]	44 (0.3)	0.813	[a]	[a]	1.00
Intraoperative Implant Related, n (%)	[a]	53 (0.4)	0.508	[a]	[a]	0.578
Neurologic Complications, n (%)	36 (1.9)	317 (2.3)	0.249	35 (1.9)	31 (1.7)	0.709
Postoperative Infection, n (%)	[a]	35 (0.3)	**0.049**	[a]	[a]	1.00
Pulmonary Embolism, n (%)	[a]	[a]	0.601	[a]	[a]	1.00
Respiratory Complications, n (%)	[a]	194 (1.4)	**0.002**	[a]	14 (0.8)	0.539
Vascular Injury, n (%)	[a]	[a]	0.586	[a]	[a]	1.00
Vocal Cord Paralysis, n (%)	[a]	17 (0.1)	0.239	[a]	[a]	1.00

[a] Value is below NRD reporting minimum of 10 or fewer cases.

Table 6
Outcomes of matched CDR versus ACDF cohorts.

Outcomes	Total	CDR	ACDF	*p*
Readmission – Before matching				
30-day Readmission, n (%)	406 (2.6)	29 (1.5)	377 (2.8)	**0.002**
90-day Readmission, n (%)	751 (4.9)	52 (2.7)	699 (5.2)	**<0.001**
Readmission – After matching				
30-day Readmission, n (%)	71 (1.9)	29 (1.6)	42 (2.2)	0.150
90-day Readmission, n (%)	126 (3.4)	52 (2.8)	74 (4.0)	0.057
Cost - Before matching				
Hospital Cost (dollars), mean (SD)		77702.45 (46127.27)	60425.12 (46410.32)	**<0.001**
Cost - After matching				
Hospital Cost (dollars), mean (SD)		77,698.54 (46252.88)	58,875.79 (45822.83)	**<0.001**
Length-of-Stay - Before matching				
LOS (days), mean (SD)		1.20 (0.82)	1.60 (2.67)	**<0.001**
Length-of-Stay - After matching				
LOS (days), mean (SD)		1.19 (0.76)	1.36 (2.78)	**0.014**

with an increased odds of readmission in only the CDR cohort (OR 4.54, 97.5 % CI 1.27–16.17, p = 0.02).

4. Discussion

While utilization of CDR continues to increase, ACDF remains the most common procedure for cervical disc disease.[11,12] Controversy still exists as to which is the ideal surgical method for treatment of cervical degenerative disc disease.[13–15] Overall, CDR has been established as noninferior to ACDF.[15–19] More recently, CDR has been found to offer greater outcomes in terms of neurological success, pain reduction, range of motion, and complication rates.[12,13,16,20–22]

The present study was a retrospective analysis using the NRD to compare the associated risks of single level ACDF and CDR procedures. Our results corroborate other recent literature which suggests CDR when indicated may be preferable to ACDF for single level procedures. Previous studies have also found CDR to be noninferior to ACDF, but confounding variables persist, such as those due to surgeon selection bias.[15–19] Here, propensity score matching affirmed previous findings of CDR noninferiority.

Table 7
Odds of complications in matched CDR vs ACDF cohorts.

Complications	OR	97.5 % CI	*p*
Dural Tear	0.33	0.09–1.23	0.099
Dysphagia	1.20	0.83–1.73	0.346
GI Complications	1.50	0.25–8.99	0.657
GU Complications	1.46	0.85–2.53	0.173
Hematoma	1.00	0.29–3.46	1.00
Intraoperative Implant-Related	0.62	0.20–1.91	0.409
Neurologic Complications	1.13	0.70–1.84	0.620
Respiratory Complications	0.71	0.32–1.61	0.415

Table 8
Risk factors associated with readmission in matched CDR vs ACDF cohorts.

Risk Factors	OR	97.5 % CI	*p*
CDR			
Chronic Pulmonary Disease	1.35	0.62–2.94	0.453
Depression	1.45	0.69–3.10	0.332
Diabetes (complicated)	**4.80**	**1.30–17.77**	**0.019**
Diabetes (uncomplicated)	1.48	0.58–13.77	0.407
Dysphagia	0.53	0.07–4.01	0.541
GU Complications	0.94	0.11–7.55	0.953
Hypothyroidism	0.48	0.11–2.06	0.326
Hypertension (uncomplicated)	1.23	0.65–2.32	0.523
Neurologic Complications	0.94	0.12–7.31	0.950
Obesity	1.11	0.48–2.58	0.806
Rheumatoid Arthritis	**4.54**	**1.27–16.17**	**0.020**
ACDF			
Chronic Pulmonary Disease	0.59	0.25–1.38	0.221
Depression	1.36	0.71–2.61	0.353
Diabetes (complicated)	**4.76**	**1.29–17.61**	**0.019**
Diabetes (uncomplicated)	1.27	0.54–2.98	0.582
Dysphagia	1.04	0.25–4.40	0.960
GU Complications	2.59	0.57–11.74	0.218
Hypothyroidism	1.80	0.80–4.05	0.156
Hypertension (uncomplicated)	1.44	0.85–2.45	0.180
Neurologic Complications	0.54	0.07–4.36	0.561
Obesity	0.80	0.36–1.81	0.595
Rheumatoid Arthritis	1.25	0.16–9.70	0.829

4.1. Baseline characteristics

Surgeons take multiple factors into account when deciding to operate, including age and preexisting comorbidities. Prior to matching, several baseline characteristics were significantly different between ACDF and CDR cohorts. In agreement with previous studies, ACDF patients tended to be older with higher comorbidity burden.[23,24] CDR tends to be performed on younger patients with decreased number of comorbidities,[25–27] corroborated in our study. However, CDR utilization for older patients continues to increase as providers become more comfortable with the procedure.[12] After matching, the prevalence of drug abuse, psychoses and weight loss were higher in the ACDF cohort. These may be key factors to consider in the management of ACDF vs CDR patients. Privately insured patients are more likely to be in the upper income and social classes. The impact of income and social strata may result in lower rates of these comorbid conditions. Furthermore, our results are in agreement with previous studies finding that patients with Medicaid are more likely to receive ACDF, while privately insured patients are more likely to receive CDR.[14,25]

4.2. Perioperative outcomes

LOS was longer for ACDF patients in both unmatched and matched analyses. Previous retrospective studies have shown decreased LOS associated with CDR.[14,25,28,29] However recent meta-analyses have found no significant difference in hospital stay between procedures.[13,20] Our results find a difference but one that is negligible to the patient and care facility. Hypertension, BMI, and diabetes have been associated with an increased LOS in CDR patients.[30] Furthermore, our results found an increased proportion of unfavorable discharges among ACDF patients. This corroborates previous analyses[25,28] and has been observed after controlling for patient baseline characteristics.[11] We also found an increased cost of index procedure for CDR patients. This is in stark contrast to other studies in which CDR has repeatedly been found to be less costly for the index procedure and for all related costs well-past 90 days postoperatively.[14,29,31] Several Markov analyses have found CDA to be more cost-effective in the long term.[32–34] Differing results in our study may be due to the use of billed cost in this study.

4.3. Adverse outcomes

Prior to matching, our results found significantly higher rates of 30-day and 90-day readmission in ACDF relative to CDR patients. However, no significant differences were found after matching. This may be attributed to higher rates of comorbidity and older age in the baseline ACDF cohort. There is a paucity of literature that compares short term readmission rates between CDR and ACDF.[29] However, having one or more comorbidities has been found to increase a patient's short term risk of readmission for either procedure.[29] In this study, diabetes status was found to be a risk factor for 90-day readmission after either procedure, while rheumatoid arthritis was a significant factor for CDR only. Diabetes has been frequently associated with adverse outcomes, such as readmission, reoperation, infection, or prolonged LOS following ACDF and CDR.[30,35–37] Our study is in agreement with prior literature. However, a recent study found no significant difference between diabetics and nondiabetics with regards to reoperation, 30- and 90-day readmission, and complication rates following ACDF.[38] Thus, the association between diabetes and adverse outcomes may require further investigation. Rheumatoid arthritis was found to be a significant predictor of 90-day readmission in CDR but not ACDF patients. This was also corroborated by a 2013 NRD study by Rumalla et al. However, the authors analyzed ACDF and CDR in tandem,[37] while in this study the two were analyzed separately after matching. Rheumatoid arthritis commonly affects the cervical spine and has been implicated as a contraindication to CDR.[39–41] This may be a key factor to consider when deciding between ACDF or CDR. Overall, readmission rates at 30 and 90 days were relatively low, suggesting that either procedure when indicated based on patient risk factors may be suitable.

Additionally, there was no difference in postoperative or intraoperative complication risk between the procedures in our matched cohort analysis. The most common adverse event for both procedures was dysphagia. While some meta-analyses find a higher rate of dysphagia with ACDF vs CDR,[16,22,42,43] other studies similar to our own do not find the difference reaching statistical significance.[44,45] It is not yet clear whether the introduction of zero-profile fusion devices may reduce these rates[46–48] in ACDF. Respiratory insufficiency, hematoma, vascular injury, surgical site infection, and dural tear are serious but uncommonly documented complications of ACDF.[49,50]

This study has several limitations to consider. First, we included data from the last quarters of 2015 and 2016. Consequently, not all readmissions may have been captured, as the NRD does not allow patients to be tracked past the calendar year. Second, a substantial portion of hospital admissions across the United States are not documented in the NRD, which may limit generalizability. Third, some admissions were missing from our original sample of the 2015 and 2016 NRDs due to technical processing issues, which may impact results.

5. Conclusions

This propensity score matched comparison between ACDF and CDR lends support to prior findings of CDR noninferiority. While ACDF patients tended to be sicker and older, similar rates of complications and 90-day readmission were found after propensity score matching. CDR patients also had shorter lengths of stay and a higher frequency of routine discharge, but greater index cost.

CRediT authorship contribution statement

Ravi S. Nunna: Writing - review & editing, Writing - original draft, Validation, Project administration, Methodology, Investigation, Conceptualization. **James S. Ryoo:** Writing - original draft, Formal analysis, Data curation. **Philip B. Ostrov:** Writing - review & editing, Writing - original draft. **Saavan Patel:** Writing - review & editing, Writing - original draft. **Periklis Godolias:** Visualization, Validation. **Zeyad Daher:** Writing - review & editing, Visualization, Validation. **Richard Price:** Writing - review & editing, Visualization. **Jens R. Chapman:** Writing - review & editing. **Rod J. Oskouian:** Writing - review & editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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