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The effect of C7-T1 fusion on clinical and patient-reported outcomes in ACDF patients

A quality outcomes database study

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Abstract

Background: The C7-T1 segment poses challenges in spinal surgery due to its biomechanical transition from the mobile cervical spine to the rigid thoracic spine, with concerns about subsidence from stress-shielding of the T1 superior endplate by the first rib. The impact of fusing C7-T1 on outcomes remains unclear relative to other levels during anterior cervical discectomy and fusion (ACDF).

Objective: In a cohort of patients undergoing ACDF, we sought to determine the impact of C7-T1 fusion on patient-reported outcome measures (PROMs) and clinical outcomes.

Methods: A retrospective cohort study using the Quality Outcome Database was conducted for patients who underwent primary single- or 2-level ACDF. The primary exposure variable was fusion of C7-T1. The primary outcome was 3-month and 12-month PROMs, including numeric rating scale for neck and arm pain, neck disability index, quality-adjusted life year (QALY) score, and patient satisfaction. Secondary outcomes included 30-day complications and 3-month readmissions and reoperations. Multivariable regression models were fitted for each outcome, controlling for baseline variables.

Results: Of 12,240 patients (age 55.8 ± 11.6 years; 48.7% male) undergoing ACDF, 4736 (38.7%) had C7-T1 fusion. On multivariable regression, fusion of C7-T1 was associated with a greater 3-month QALY score (odds ratio [OR] = 1.142; 95% confidence interval [CI]: 1.055–1.237; $p < 0.001$) and lower rate of readmission (OR = 0.760; 95% CI: 0.625–0.924; $p = 0.006$), with no association to other PROMs, patient satisfaction, complications, and reoperation ($p > 0.05$). On subanalysis of 4103 myelopathic patients, C7-T1 fusion was only associated with lower odds of 3-month readmission (OR = 0.602; 95% CI: 0.420–0.864; $p = 0.006$).

Conclusion: C7–T1 fusion was associated with a better 3-month QALY score and a lower rate of readmission. Myelopathy patients with C7-T1 fusion were also less likely to be readmitted within 3 months of surgery. C7-T1 fusion was not associated with any other outcome. Our results suggest comparable outcomes when fusing C7-T1, which may be useful when counseling patients facing surgery for pathology at this level.

Abbreviations: ACDF = anterior cervical discectomy and fusion, PROMs = patient-reported outcome measures, QALY = quality-adjusted life year, CTJ = cervicothoracic junction, PCF = posterior cervical fusion, QOD = quality outcomes database, BMI = body mass index, NRS = Numeric rating scale, mJOA = modified Japanese Orthopaedic Association, CAD = coronary artery disease, COPD = chronic obstructive pulmonary disease, NDI = neck disability index, OR = odds ratio, CI = confidence interval.

Keywords: anterior cervical discectomy and fusion, C7-T1 fusion, cervicothoracic junction, patient-reported outcome measures

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1. Introduction

Anterior cervical discectomy and fusion (ACDF) is used to treat various cervical conditions such as myelopathy, disc herniation, and degenerative disc disease. It has been demonstrated to provide substantial reductions in pain and symptoms, with a patient-reported success rate between 85% and 95%.[1] Nonetheless, adjacent segment degeneration and pseudarthrosis are known complications.[1–3] To minimize complications and associated need for reoperations, the clinical significance of the cervicothoracic junction (CTJ) has been explored.[3–7]

As a transitional region of the spine, the CTJ is subject to significant static and dynamic stressors, potentially predisposing it to the development of pathology.[3,8] Some authors have proposed that extension of cervical constructs into the thoracic spine may minimize complication risk.[5,9] This idea has been explored in relation to posterior cervical fusion (PCF).[5–7,9] Among a cohort of 438 patients undergoing PCF, extending constructs beyond the CTJ led to significantly lower rates of mechanical failure and revision surgery.[5] Notably, extension to T2 led to superior outcomes than T1.[5] Literature exploring this topic with regard to ACDF is far more limited, but Louie et al.[3] found that among 83 patients undergoing ACDF, there were no differences in rates of adjacent segment degeneration or rates of reoperation between fusions terminating above or below the CTJ.

A notable gap persists in the existing literature regarding the significance of the CTJ in ACDF. To better inform surgical planning and patient counseling, we strove to better delineate the relationship of the CTJ in comparison to other spinal levels. Thus, among a cohort of patients undergoing ACDF, we aimed to determine the impact of C7-T1 fusion on patient-reported outcome measures (PROMs) and clinical outcomes.

2. Materials and methods

2.1. Study design

A retrospective cohort analysis was performed utilizing data obtained from the Quality Outcomes Database (QOD), a national multicenter spine surgery registry containing prospectively collected patient data.[10] The QOD's inclusion criteria consist of patients ≥ 18 years undergoing elective spinal surgery for degenerative spine diseases.[10] Patients were excluded from the QOD if they underwent spinal surgery due to traumatic injury, tumors, spinal infections, or if they were incarcerated at the time of surgery.[11] All data were obtained from and defined according to standardized protocols within the QOD.

2.2. Patient population

The cervical module of the QOD was queried for patients who underwent 1- to 2-level ACDF surgery. Inclusion criteria consisted of adult patients who were undergoing primary elective 1- or 2-level ACDF and had a surgical indication of degenerative pathology. Exclusion criteria included age under 18 years; diagnoses of infection, tumor, deformity, or trauma; and concomitant arthrodesis or instrumentation.

2.3. Exposure variables

The primary independent variable was fusion of C7-T1. Demographic variables and baseline characteristics consisted of age, sex, body mass index (BMI), comorbidities, smoking status, clinical characteristics, and prior spine surgery.

2.4. Outcome variable

The primary outcome of interest was 3-month and 12-month PROMs, including numeric rating scale (NRS) scores for neck and arm pain and quality-adjusted life year (QALY) scores.[12] Secondary outcomes included 30-day complications and 3-month readmissions and reoperations.

2.5. Statistical analysis

Descriptive statistics were used to summarize demographic variables and baseline characteristics. Categorical variables were presented as frequencies and percentages, whereas continuous data were presented as means and standard deviations. Bivariate analysis was conducted to compare baseline variables and outcomes between patients with and without C7-T1 fusion, using pairwise deletion for missing data. Pearson's chi-square was used to compare categorical variables. Wilcoxon rank sum test was used to compare continuous variables. Separate multivariable regression models were fitted for each of the endpoints on C7-T1 being fused, including all demographic variables, clinical characteristics (such as reoperation), and baseline PROMs as covariates. Logistic regression was used for binary outcomes and linear regression was used for continuous outcomes such as PROMs. Similarly, a subanalysis and separate multivariable regression model for myelopathy patients was further conducted with modified Japanese Orthopaedic Association (mJOA) scores.[13] Listwise deletion was used for missing data in regression analysis. A p value < 0.05 was considered statistically significant. All statistical analyses were performed using R version 4.1.[14]

3. Results

3.1. Demographics and clinical characteristics

Of the ACDF patients queried, 12,240 patients met the inclusion criteria. Patients had a mean age of 56.7 ± 11.8 years, a mean BMI of 30.43 ± 6.57, and 48.0% (3603) were male (Table 1). Among these patients, 38.7% (4736) underwent C7-T1 fusion. On bivariate analysis, patients who underwent C7-T1 fusion were younger, had lower BMI, and were more likely to be smokers, have comorbidities, and have a history of prior spine surgery compared with those who did not undergo C7-T1 fusion.

Additionally, these patients exhibited less myelopathy and cervical instability.

3.2. PROMs and clinical outcomes

At 3 months, patients with C7-T1 fusion reported lower NRS-arm (1.94 ± 2.61 vs. 2.14 ± 2.75; p = 0.010) and neck pain (2.65 ± 2.53 vs. 2.79 ± 2.63; p = 0.039), neck disability index (NDI)% (20.0 ± 17.5 vs. 21.1 ± 17.6; p = 0.002), and QALY (0.793 ± 0.187 vs. 0.771 ± 0.194; $p < 0.001$) when compared with patients without C7-T1 fusion (Table 2). At 12 months, patients with C7-T1 fusion reported lower NDI% (17.8 ± 18.8 vs. 18.6 ± 18.8; p = 0.036) and higher QALY (0.800 ± 0.202 vs. 0.778 ± 0.210; $p < 0.001$) when compared with patients without C7-T1 fusion. Further, patients with C7-T1 fusion had fewer complications (8.7% vs. 9.9%; p = 0.036) and readmissions (3.5% vs. 5.3%; $p < 0.001$) than patients without C7–T1 fusion. There was no significant difference in patient satisfaction and reoperation rates between the cohorts ($p > 0.05$). To note, there was drop out from baseline to 3 and 12 months (Table 2).

On multivariable regression controlling for all demographics, clinical characteristics, and baseline PROMs (Tables 1 and 2), fusion of C7-T1 was significantly associated with a greater 3-month QALY score (odds ratio [OR] = 1.142; 95% confidence interval [CI]: 1.055–1.237; $p < 0.001$) and lower rate of readmission (OR = 0.760; 95% CI: 0.625–0.924; p = 0.006) (Table 3). There was no association between C7-T1 fusion and any other outcome ($p > 0.05$). Likewise, comparison was used for when there was missing data.

3.3. Subanalysis of myelopathy patients

Of the 4103 myelopathic patients in our cohort, 1151 (28.1%) had C7-T1 fusion (Table 1). On bivariate analysis, patients with C7-T1 fusion had greater 12-month patient satisfaction (69.0% vs. 63.9%; p = 0.039), better 3-month (14.46 ± 2.51 vs. 14.22 ± 2.54; p = 0.009) and 12-month (14.38 ± 2.61 vs. 14.11 ± 2.71; p = 0.045) mJOA scores, and fewer complications (9.3% vs. 11.6%; p = 0.038) and readmissions (4.1% vs. 6.9%; p = 0.001) than patients without C7-T1 fusion (Table 4). On multivariable regression, C7-T1 fusion was associated with lower odds of readmission (OR = 0.602; 95% CI: 0.420–0.864; p = 0.006), with no association to other outcomes ($p > 0.05$) (Table 5).

4. Discussion

The present study aimed to elucidate the significance of C7-T1 fusion in ACDF by assessing PROMs as well as rates of complications, readmissions, and reoperations. Although bivariate analyses suggested that C7-T1 fusion positively impacted postoperative PROMs, pain scores, and complication rates, only the 3-month QALY score and readmission were significantly affected by C7-T1 fusion following multivariate analysis. Similar results were noted when analyzing only myelopathic patients within the cohort; multivariate analysis revealed lower odds of 90-day readmission as the only significant difference following C7-T1 fusion. Consistent with the large sample size, both the primary and subgroup analyses were sufficiently powered (> 80%) to detect clinically meaningful differences in the reported outcomes. These findings

Table 1

Demographic and clinical characteristics of patients undergoing ACDF.

Variables	*N*	C7-T1 not fused	C7-T1 fused	Total	*p* value
Age, mean ± SD	12,269	56.7 ± 11.8	54.2 ± 11.1	55.8 ± 11.6	**< 0.001**
Sex: male, *n* (%)	12,266	3603 (48.0%)	2358 (49.8%)	5961 (48.7%)	0.056
BMI, mean ± SD	12,255	30.43 ± 6.57	30.64 ± 6.51	30.51 ± 6.55	**0.038**
Comorbidities					
Diabetes, *n* (%)	12,261	1463 (19.5%)	851 (18.0%)	2314 (18.9%)	**0.036**
Peripheral vascular disease, *n* (%)	12,222	162 (2.2%)	78 (1.6%)	240 (2.0%)	**0.046**
CAD, *n* (%)	12,223	683 (9.1%)	315 (6.7%)	998 (8.2%)	< **0.001**
COPD, *n* (%)	12,227	553 (7.4%)	277 (5.9%)	830 (6.8%)	**0.001**
Anxiety, *n* (%)	12,231	1773 (23.6%)	1152 (24.3%)	2925 (23.9%)	0.376
Depression, *n* (%)	12,232	1905 (25.4%)	1188 (25.1%)	3093 (25.3%)	0.707
Osteoarthritis, *n* (%)	12,156	1667 (22.4%)	884 (18.7%)	2551 (21.0%)	< **0.001**
Smoker, *n* (%)	12,198	1524 (20.4%)	880 (18.7%)	2404 (19.7%)	**0.020**
Clinical characteristics, *n* (%)	12,240				
Radiculopathy		5573 (74.3%)	4125 (87.1%)	9698 (79.2%)	**< 0.001**
Myelopathy		2952 (39.3%)	1151 (24.3%)	4103 (33.5%)	**< 0.001**
Disc herniation		3625 (48.3%)	2693 (56.9%)	6318 (51.6%)	**< 0.001**
Foraminal stenosis		4328 (57.7%)	2964 (62.6%)	7292 (59.6%)	**< 0.001**
Central stenosis		3923 (52.3%)	2608 (55.1%)	6051 (49.4%)	**< 0.001**
Cervical instability		367 (4.9%)	138 (2.9%)	505 (4.1%)	**< 0.001**
Prior spine surgery	12,240	3228 (43.8%)	1975 (41.7%)	5263 (43.0%)	**0.021**

BMI = body mass index, CAD = coronary artery disease, COPD = chronic obstructive pulmonary disease. *N* = total number of patients included in analysis for variable.
$p < 0.05$ in bold indicates statistical significance.

Table 2

Clinical and patient-reported outcome measures of patients undergoing ACDF.

Outcome variable		*N*	C7-T1 not fused	C7-T1 fused	Total	*p* value
NRS-Arm	Preoperative	12,189	5.55 ± 3.11	5.94 ± 2.94	5.70 ± 3.05	**< 0.001**
	Postoperative (3 mo)	8689	2.14 ± 2.75	1.94 ± 2.61	2.06 ± 2.70	**0.010**
	Postoperative (12 mo)	5608	2.04 ± 2.78	2.02 ± 2.75	2.03 ± 2.77	0.830
NRS-Neck	Preoperative	12,217	6.16 ± 2.81	6.12 ± 2.78	6.14 ± 2.80	0.223
	Postoperative (3 mo)	8716	2.79 ± 2.63	2.65 ± 2.53	2.74 ± 2.59	**0.039**
	Postoperative (12 mo)	5619	2.60 ± 2.79	2.48 ± 2.72	2.55 ± 2.76	0.133
NDI	Preoperative	12,240	41.6 ± 18.5	42.0 ± 18.1	41.8 ± 18.3	0.306
	Postoperative (3 mo)	8731	21.1 ± 17.6	20.0 ± 17.5	20.7 ± 17.6	**0.002**
	Postoperative (12 mo)	5617	18.6 ± 18.8	17.8 ± 18.8	18.3 ± 18.0	0.036
QALY	Preoperative	12,197	0.582 ± 0.217	0.587 ± 0.215	0.584 ± 0.216	0.162
	Postoperative (3 mo)	8646	0.771 ± 0.194	0.793 ± 0.187	0.780 ± 0.192	**< 0.001**
	Postoperative (12 mo)	5574	0.778 ± 0.210	0.800 ± 0.202	0.786 ± 0.207	**< 0.001**
Patient satisfaction	Postoperative (3 mo)	8748	3750 (69.0%)	2333 (70.4%)	6083 (69.5%)	0.151
	Postoperative (12 mo)	5668	1450 (70.4%)	1450 (70.4%)	3904 (68.9%)	0.058
Complications		11,766	714 (9.9%)	397 (8.7%)	10,655 (90.6%)	**0.036**
Revision		8767	35 (0.6%)	16 (0.5%)	51 (0.6%)	0.337
Readmission		11,626	380 (5.3%)	160 (3.5%)	540 (4.6%)	**< 0.001**

N = total number of patients included in analysis for variable, NDI = neck disability index, NRS = numeric rating scale, QALY = quality-adjusted life year score.
$p < 0.05$ in bold indicates statistical significance.

suggest that C7-T1 fusion has minimal impact on most patient-reported and clinical outcomes in the context of single- and 2-level ACDF.

Our study found that ACDF constructs through the CTJ did not impact complication rates. While literature investigating fusion of the CTJ via an anterior approach is sparse, the majority of existing literature has focused on adjacent segment disease. For example, Hilibrand et al.[4] found that adjacent segment disease occurs most commonly at the C4–C5, C5–C6, and C6–C7 levels, with risk decreasing notably at the C3–C4 and C7–T1 levels. The authors also noted that with increased length of the overall ACDF construct, the risk of adjacent segment disease decreased.[4] Concurrent findings were published by van Eck et al.[15] among their cohort of 672 patients. In an *in vitro* study, Cheng et al.[9] noted that following anterior cervical fusion procedures spanning the CTJ, bending motion resulted in the least intradiscal pressure at the T2 to T3 level. Based on this finding, the authors suggested that termination of anterior constructs at the T2 level may be most beneficial in decreasing adjacent segment pathology.[9] The biomechanical rationale has been proposed by several authors, suggesting that without including the CTJ in the fusion construct, 2 rigid levers are created between the high-motion cervical spine and lower-motion thoracic spine, potentially predisposing to the development of pathology.[9,16,17]

There were no observed differences in PROMs, pain scores, or patient satisfaction between those who underwent ACDF with C7-T1 fusion and those without. Our findings are corroborated in the setting of PCF,[5,7,18] with scant literature addressing ACDF in this context. Lee et al.[7] noted that among 46 patients undergoing PCF, there were no differences in arm and neck pain between patients receiving constructs terminating at C7 compared with those extending to T1. Similarly, both Okamoto et al.[18] and Labrum et al.[5] found no differences in mJOA, NRS-neck pain, NDI, and other PROMs between fusions

Table 3

Multivariable regression model of clinical and patient-reported outcomes in patients undergoing ACDF.

Outcome variable		OR (95% CI)	*p* value
NRS-Arm	Postoperative (3 mo)	0.930 (0.855–1.012)	0.092
	Postoperative (12 mo)	1.029 (0.925–1.145)	0.602
NRS-Neck	Postoperative (3 mo)	0.959 (0.886–1.038)	0.301
	Postoperative (12 mo)	0.942 (0.851–1.042)	0.247
NDI	Postoperative (3 mo)	0.958 (0.887–1.036)	0.283
	Postoperative (12 mo)	0.961 (0.871–1.061)	0.431
QALY	Postoperative (3 mo)	1.142 (1.055–1.237)	**< 0.001**
	Postoperative (12 mo)	1.051 (0.929–1.190)	0.430
Patient satisfaction	Postoperative (3 mo)	0.989 (0.896–1.092)	0.823
	Postoperative (12 mo)		
Complications		0.934 (0.818–1.068)	0.320
Readmission		0.760 (0.625–0.924)	**0.006**

NDI = neck disability index; NRS = numeric rating scale; QALY = quality-adjusted life year score.
$p < 0.05$ in bold indicates statistical significance.

Table 4

Clinical and patient-reported outcome measures of myelopathy patients undergoing ACDF.

Outcome variable		*N*	C7-T1 not fused	C7-T1 fused	Total	*p* value
NRS-Arm	Preoperative	4083	4.98 ± 3.35	5.29 ± 3.23	5.07 ± 3.32	**0.012**
	Postoperative (3 mo)	2873	2.29 ± 2.85	2.14 ± 2.80	2.25 ± 2.83	0.329
	Postoperative (12 mo)	1847	2.23 ± 2.90	2.32 ± 2.84	2.25 ± 2.88	0.303
NRS-Neck	Preoperative	4094	5.52 ± 3.12	5.66 ± 3.04	5.56 ± 3.10	0.254
	Postoperative (3 mo)	2882	2.72 ± 2.68	2.70 ± 2.62	2.71 ± 2.66	0.963
	Postoperative (12 mo)	1856	2.55 ± 2.81	2.56 ± 2.74	2.55 ± 2.79	0.709
NDI	Preoperative	4103	38.9 ± 20.0	40.6 ± 19.3	39.4 ± 19.8	0.011
	Postoperative (3 mo)	2890	21.4 ± 17.6	21.8 ± 18.1	21.5 ± 17.8	0.776
	Postoperative (12 mo)	1860	19.0 ± 19.5	19.1 ± 18.9	19.1 ± 19.3	0.748
QALY	Preoperative	4079	0.581 ± 0.217	0.576 ± 0.219	0.579 ± 0.217	0.405
	Postoperative (3 mo)	2856	0.753 ± 0.195	0.758 ± 0.199	0.754 ± 0.196	0.232
	Postoperative (12 mo)	1844	0.755 ± 0.215	0.759 ± 0.211	0.756 ± 0.214	0.884
Patient satisfaction	Postoperative (3 mo)	2891	1366 (65.3%)	531 (66.4%)	1897 (65.6%)	0.596
	Postoperative (12 mo)	1867	871 (63.9%)	347 (69.0%)	1218 (65.2%)	**0.039**
mJOA	Preoperative	3843	12.17 ± 2.89	12.59 ± 2.74	12.29 ± 2.85	**< 0.001**
	Postoperative (3 mo)		14.22 ± 2.54	14.46 ± 2.51	14.29 ± 2.53	**0.009**
	Postoperative (12 mo)		14.11 ± 2.71	14.38 ± 2.61	14.18 ± 2.68	**0.045**
Complications		3946	332 (11.6%)	102 (9.3%)	434 (11.0%)	**0.038**
Revision		2897	16 (0.8%)	4 (0.5%)	20 (0.7%)	0.447
Readmission		3903	194 (6.9%)	45 (4.1%)	239 (6.1%)	**0.001**

mJOA = modified Japanese Orthopaedic Association score, *N* = total number of patients included in analysis for variable, NRS = numeric rating scale, NDI = neck disability index, QALY = quality-adjusted life year score.
$p < 0.05$ in bold indicates statistical significance.

that did or did not cross the CTJ at 1-year follow-up post-PCF. Nonetheless, the potential increased invasiveness of extending fusion constructs into the thoracic region remains another factor to consider. For example, even in the setting of similar PROMs, the Okamoto cohort of patients receiving fusion crossing the CTJ experienced significantly longer surgical times, increased blood loss, and higher rates of peri- and postoperative complications than those with constructs terminating at C7.[18] Our findings are some of the first to report on PROMs, pain scores, and patient satisfaction following ACDF, investigating the CTJ. While existing literature focused on posterior approaches provides valuable insight, future work focused on anterior approaches is needed.

The present research must be considered with some limitations. Primarily, the retrospective nature of this work using QOD data makes it a nonrandomized study with patient and procedure selection being surgeon-dependent, introducing bias. Further, our included follow-up was only 12 months, potentially missing clinical and patient outcomes over a longer timeframe. We were also limited by the granularity of the data in each group, with exact indications and specifics of each operation unknown, such as the number of fixed segments. Lastly, mixed-effects models for the PROM

Table 5

Multivariable ordinal logistic regression model of clinical and patient-reported outcomes in myelopathy patients undergoing ACDF.

Outcome variable		OR (95% CI)	*p* value
NRS-Arm	Postoperative (3 mo)	0.964 (0.819–1.136)	0.664
	Postoperative (12 mo)	1.081 (0.877–1.332)	0.465
NRS-Neck	Postoperative (3 mo)	1.012 (0.865–1.183)	0.882
	Postoperative (12 mo)	1.003 (0,820–1228)	0.975
NDI	Postoperative (3 mo)	1.031 (0.887–1.199)	0.691
	Postoperative (12 mo)	0.959 (0.788–1.165)	0.671
QALY	Postoperative (3 mo)	0.984 (0.810–1.108)	0.498
	Postoperative (12 mo)	0.955 (0.786–1.161)	0.647
Patient Satisfaction	Postoperative (3 mo)	0.986 (0.817–1.189)	0.881
	Postoperative (12 mo)	1.211 (0.949–1.546)	0.125
mJOA	Postoperative (3 mo)	0.947 (0.810–1.108)	0.498
	Postoperative (12 mo)	1.035 (0.847–1.265)	0.739
Complications		0.818 (0.638–1.050)	0.115
Readmission		0.602 (0.420–0.864)	**0.006**

mJOA = modified Japanese Orthopaedic Association score, NDI = neck disability index, NRS = numeric rating scale, QALY = quality-adjusted life year score.
$p < 0.05$ in bold indicates statistical significance.

regression analysis could have offered additional insight; however, due to the structure of the QOD and scope of analysis, separate regression models at each time point were selected instead. Similarly, no formal correction for multiple comparisons was conducted. While multiple comparisons may increase the risk of type I error, the primary outcomes were predefined based on clinical relevance, which helps mitigate this concern. Considering these limitations and the current dearth of literature examining fusion of the CTJ in ACDF, it is important to continue examining this subject to determine any potential advantages and drawbacks.

5. Conclusion

The C7-T1 segment presents difficulty in spinal surgery due to its biomechanical transition from the mobile cervical spine to the rigid thoracic spine. The impact of fusing C7-T1 on outcomes remains unclear in the literature relative to other levels during ACDF. Our analysis demonstrated that C7-T1 fusion was associated with some improved short-term quality and clinical outcome measures. C7-T1 fusion versus without fusion were not significantly different from any other outcome. Our results suggest comparable outcomes when fusing C7-T1, which may be useful for surgeons in determining appropriate treatment and counseling patients facing surgery for pathology at this level.

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Ethical statement

Ethical compliance was ensured by Vanderbilt University Medical Center IRB. This study met IRB exempt under 45 CFR 46.104(d)(4) as secondary research using de-identified data from the national Spine Quality Outcomes Database (QOD). Per the QOD participants' consent was obtained.

Conflicts of interest

Dr. Stephens, Associate Editor-in-Chief of *Spine Research*, who serves as a teaching consultant for Globus and receives institutional research support from Globus and Stryker Spine, was not involved in the peer-review process or any editorial decisions regarding this manuscript, and the peer-review process was instead handled independently by other qualified editors to minimize potential bias. Dr. Abtahi receives institutional research support from Stryker Spine. Dr. Gardocki is a consultant and teaching surgeon for Joimax, a consultant for Arthrex, a teaching surgeon and consultant with royalties for Integrity Implants, and a consultant with royalties for Spineology. Dr. Pennings is a consultant for 3Spine and Steamboat Orthopedic and Spine Institute. Dr. Zuckerman reports being an unaffiliated neurotrauma consultant for the National Football League. No other perceived conflict of interest by any of the listed authors.

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Data availability statement

The data sets used during and/or analyzed during the current study are publicly available via the Quality Outcomes Data base (QOD) Spine Registry. Please contact the corresponding author regarding related questions.

Author contributions

OZ, MYJ—interpretation of the analysis, drafting of the manuscript.
HN, JSP—formal data analysis, drafting of manuscript.
JFB, MWY, MFB—interpretation of the analysis, drafting of manuscript.
RJG, JGL-P, SLZ, AMA, and BFS—conceptualization, review, and editing of the final manuscript.

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