Early Voice and Swallowing Disturbance Incidence and Risk Factors After Revision Anterior Cervical Discectomy and Fusion Using a Multidisciplinary Surgical Approach: A Retrospective Cohort Evaluation of a Prospective Database

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BACKGROUND AND OBJECTIVES: Dysphagia and vocal cord palsy (VCP) are common otolaryngological complications after revision anterior cervical discectomy and fusion (rACDF) procedures. Our objective was to determine the early incidence and risk factors of VCP and dysphagia after rACDF using a 2-team approach.

METHODS: Single-institution, retrospective analysis of a prospectively collected database of patients undergoing rACDF was enrolled from September 2010 to July 2021. Of 222 patients enrolled, 109 patients were included in the final analysis. All patients had prior ACDF surgery with planned revision using a single otolaryngologist and single neurosurgeon. MD Anderson Dysphagia Inventory and fiberoptic endoscopic evaluation of swallowing (FEES) were used to assess dysphagia. VCP was assessed using videolaryngostroboscopy.

RESULTS: Seven patients (6.7%) developed new postoperative VCP after rACDF. Most cases of VCP resolved by 3 months postoperatively (mean time-to-resolution 79 ± 17.6 days). One patient maintained a permanent deficit. Forty-one patients (37.6%) reached minimum clinically important difference (MCID) in their MD Anderson Dysphagia Inventory composite scores at the 2-week follow-up (MCID decline of ≥6), indicating new clinically relevant swallowing disturbance. Forty-nine patients (45.0%) had functional FEES Performance Score decline. On univariate analysis, there was an association between new VCPs and the number of cervical levels treated at revision ($P = .020$) with long-segment rACDF (≥4 levels) being an independent risk factor ($P = .010$). On linear regression, there was an association between the number of levels treated previously and at revision for FEES Performance Score decline ($P = .045$ and $P = .002$, respectively). However, on univariate analysis, sex, age, body mass index, operative time, alcohol use, smoking, and individual levels revised were not risk factors for reaching FEES Performance Score decline nor MCID at 2 weeks postoperatively.

CONCLUSION: VCP is more likely to occur in long-segment rACDF but is often temporary. Clinically relevant and functional rates of dysphagia approach 37% and 45%, respectively, at 2 weeks postoperatively after rACDF.

KEY WORDS: Anterior cervical discectomy and fusion, Revision, Reoperation, Vocal cord paralysis, Dysphagia, Dysphonia, Head and neck surgery

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ABBREVIATIONS: ACDF, anterior cervical discectomy and fusion; **FEES,** fiberoptic endoscopic evaluation of swallowing; **MCID,** minimum clinically important difference; **MDADI,** MD Anderson Dysphagia Inventory; **PAS,** Penetration-Aspiration scale; **PROM,** patient-reported outcome measurement; **rACDF,** revision ACDF; **RLN,** recurrent laryngeal nerve; **SPS,** Swallowing Performance Scale; **VCP,** vocal cord palsy; **VLS,** videolaryngostroboscopy.

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Anterior cervical discectomy and fusion (ACDF) is one of the most common spine procedures performed in the United States with over 130 000 ACDFs performed annually. Surgical volume is projected to increase approximately 13 percent from 2020 to 2040.[1,2] The anterior approach to the cervical spine is well tolerated by patients and effective for various cervical pathology.[3,4] However, it is estimated that between 4% and 11% of patients will require revision surgery by 2 years for new degenerative disease, adjacent segment disease, pseudoarthrosis, hardware failure, or infection.[5,6] Such revision surgery poses an increased adverse event rate on patients partially due to scarring that disrupts the requisite anatomy and normal anatomic planes.[7]

Dysphagia and dysphonia or vocal cord palsy (VCP) are common otolaryngological complications after ACDF procedures.[8] Reported incidence of these complications after primary or revision ACDF (rACDF) varies widely in the literature.[5-10] In 2018, our group was the first to demonstrate that a 2-team approach using a head and neck surgeon for anterior cervical exposures during revision ACDF is safe and effective in reducing the rates of dysphagia and VCP in a sizeable cohort of patients.[11] Since its completion, a few other studies have retrospectively examined otolaryngological complications after rACDF procedures.[12,13] Despite these studies, there remains a need in the literature to better understand and manage dysphagia and VCP after revision anterior cervical spine surgery.

The primary objective of this study was to evaluate the early incidence and risk factors of voice disturbance and swallowing complications before and after revision anterior cervical spine surgery using a 2-team operative approach. In this study, we provide an updated cohort of otolaryngological outcomes from our previous study.[11]

METHODS

After Institutional Review Board approval (IRB-300010452), 222 patients were identified by a single spinal neurosurgeon at a high-volume academic institution and enrolled in a nonrandomized, prospective study between May 1, 2010, and July 31, 2021. Eligibility criteria included that all patients had undergone at least 1 prior right-sided approach ACDF surgery and were scheduled to undergo reoperative ACDF surgery using a multidisciplinary approach consisting of a single head and neck surgeon and neurosurgeon. If there were missing or incomplete data, if the patient was lost to follow-up, or did not provide consent for the study, then that patient was excluded from the final analysis. Rather than a random or probability sample, patients were selected on convenience due to patient availability and ease of enrollment.[14] This study complies with the Strengthening the Reporting of Observational Studies in Epidemiology criteria for observational studies.[15]

Revision ACDF Using a 2-Team Approach

One hundred nine patients were included. A baseline preoperative assessment was conducted for all patients on their prior surgery. Data collected included demographic information, number of previous anterior cervical surgeries, number of cervical levels treated, prior approach side, diagnosis, and existing complications such as VCP or abnormality of swallowing by fiberoptic endoscopic assessment of swallowing (FEES). Consent was obtained before the procedure. Revision transcervical approach was performed using a right anterior transcervical technique through the existing scar tissue. The head and neck surgeon and neurosurgeon worked in tandem to dissect through the existing scar tissue to safely land on the anterior cervical spine. The approach through the existing scar is similar to the traditional transcervical approach performed by the senior neurosurgeon. However, these revisions often require sharper and wider dissection to release tension on adherent anatomy to minimize the risk of retraction injury to the recurrent laryngeal nerve (RLN), esophagus, or vascular structures in the neck.[11,12,16] This can be especially difficult if the patient has had more than 1 revision transcervical approach. It is advantageous to have an experienced and knowledgeable head and neck surgeon, who has performed countless neck dissections, assist with dissection where identification, dissection, and protection of distorted anatomy is critical to the success of the approach.

Swallowing Assessment

All patients underwent preoperative and 2-week follow-up assessments by a senior certified speech and language pathologist. There was a subjective patient-reported outcome measurement (PROM) and objective functional components to the speech and language pathologist assessment. The MD Anderson Dysphagia Inventory (MDADI) was completed to gather the subjective, patient-reported component (**Supplementary Digital Content 1,** http://links.lww.com/NEU/D975). In this validated, self-administered questionnaire, the patient answers 20 questions according to a 5-point Likert scale: strongly agree, agree, no opinion, disagree, or disagree strongly. These are then quantified and used to provide a score between 20 and 100 for general, functional, emotional, and physical domains.[17] Minimum clinically important difference (MCID) in swallowing function was defined as a 6-point between-group decline in composite scores as established by Okano et al.[18] Patients who met postoperative MCID were defined as having a new onset, clinically relevant dysphagia.

Objective functional evidence of dysphagia was evaluated preoperatively and postoperatively by a FEES test. The FEES test has been shown to be a reliable assessor of dysphagia in patients undergoing ACDF.[19] A Direct Pharyngeal Phase Assessment was used and rated according to the Penetration-Aspiration scale (PAS)[20] and the Swallowing Performance Scale (SPS).[21] Existing abnormalities of swallowing were defined as having either (1) a rating of ≥3 on the SPS, indicating at least mild impairment, or (2) a rating of ≥2 on the PAS, indicating any material entering the airway during swallowing. Having a score of ≤2 on the SPS was classified as within functional limits and not considered an abnormality of swallowing. FEES Performance Score decline was defined as any negative change in postoperative SPS and/or PAS at the 2-week follow-up and was considered new-onset functional dysphagia. Patients having a postoperative abnormality that was not present on the preoperative FEES were considered to new functional abnormality of swallowing. Although a swallowing decline on the SPS scale could have been from 1 (normal) to 2 (within functional limits) rating, the authors believe that any decline on the FEES Performance Score would create more stringent criteria and thus capture any functional change in swallowing performance postoperatively.

Vocal Cord Paralysis Assessment

Functional assessment of vocal cord function was made by preoperative and postoperative videolaryngostroboscopy (VLS). New VCP was defined as the development of either visually reduced motion or total paralysis of a vocal cord on postoperative VLS at the 2-week follow-up. Patients with new VCP postoperatively were followed until improvement or resolution. There were 4 patients with residual VCP before rACDF at our institution. These patients were excluded from analysis.

Statistical Analysis

Descriptive statistics were evaluated for all variables with counts and percentages for categorical variables, means and standard deviations for normally distributed continuous variables, and medians with interquartile range for non-normally distributed continuous variables. Age at revision surgery and operative time were assessed as normally distributed, continuous variables with differences evaluated according to the development of VCP, FEES SPS decline, and MDADI MCID using the Student independent *t*-test. Differences in proportions for the categorical variables of sex, body mass index (BMI), smoking status, alcohol use, diagnosis, FEES scores, and functional abnormalities of swallowing were evaluated using the Fisher exact test. Comparisons of differences in proportions of number of previous surgeries, number of cervical levels fused previously or at revision, and months since previous surgery were evaluated using the Wilcoxon rank-sum test. Pre-rACDF and post-rACDF MDADI scores expressed as median with interquartile range were evaluated using the Wilcoxon signed-rank test. A linear regression was performed to determine the association of the changes in FEES Performance Scores and changes in MDADI scores. An alpha level of 0.05 was considered statistically significant. Analyses were performed using STATA (StataCorp LLC) version 17, standard edition version 9.4.[22]

RESULTS

One hundred nine patients were included in the final analysis (Figure). Forty-eight patients (44.0%) were male with an average age of 52.2 ± 9.2 years. Over half (53.2%) endorsed regular alcohol use, and 17.4% reported being a current smoker. The most common diagnosis reported was radiculopathy from spondylosis (81.7%), followed by pseudoarthrosis/failed fusion (16.5%), instability (15.6%), and myelopathy (9.2%). Approximately 33.7% of patients had 2 or more ACDF surgeries before being enrolled for revision at our institution. Four patients had existing VCPs, and 5.5% (6/109) had an existing abnormality of swallowing by FEES before their revision surgery. If any abnormality was noted on preoperative FEES assessment, this did not necessarily rise to the level of abnormality of swallowing defined by the SPS or PAS scale. Complete demographics and existing abnormalities are listed in Table 1.

Vocal Cord Palsy

Table 2 presents the risk factors examined in the analysis for new-onset VCP at 2 weeks postoperatively. The incidence of new-onset VCP after rACDFs was 6.7% (7/105). All these patients were followed by otolaryngology with a mean time to VCP resolution on VLS by 79 ± 17.6 days. One patient maintained a permanent deficit. On univariable analysis, there was an association between new postoperative VCP and the number of cervical levels operated on during the revision surgery at our institution (P = .020) (Table 2). When separated by ≤3 levels or ≥4 levels, there was an association with VCP in the longer segment group (P = .010). There was a trend toward association with new VCP and number of previous cervical levels treated (P = .065). However, no other risk factors were identified, including BMI (P = .94) or BMI (separated by obesity class, P = .43), current smoking status (P = .61), alcohol use (P = .70), operative time (P = .56), time since last ACDF surgery (P = .79), number of previous operations (P = .70), or number of cervical levels treated previously (P = .24).

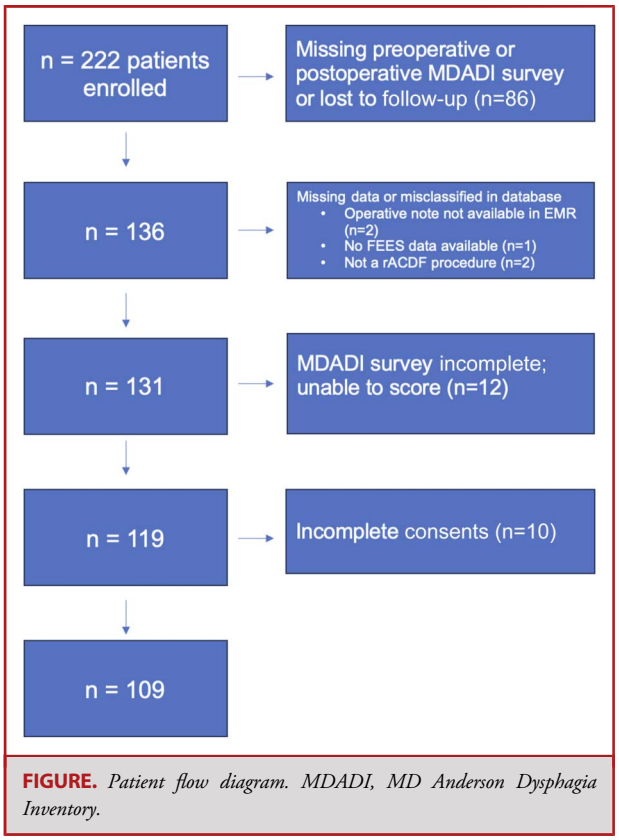

FIGURE. *Patient flow diagram. MDADI, MD Anderson Dysphagia Inventory.*

Swallowing Dysfunction

Table 3 presents the analysis of patient factors affecting dysphagia at 2 weeks postoperatively. After 2 weeks, 37.6% (41/109) of patients reported a composite MDADI decline of ≥6, meeting MCID. The number of cervical levels treated previously or at revision did not show an association of increased risk of meeting MDADI MCID. Analysis of individual cervical levels treated at revision similarly did not meet statistical significance for association. No other risk factors were identified between those that met MDADI MCID and those that did not. When analyzing by

TABLE 1. Baseline Characteristics of Study Population

Variable	No. of patients, N = 109, (%)
Demographic data	
Male sex	48 (44.0)
Mean age, y	52.2 ± 9.2
Age ≥60 y[a]	22 (20.2)
BMI ≥30	35 (32.1)
Current smoker	19 (17.4)
Alcohol use	58 (53.2)
Diagnosis[a]	
Radiculopathy	89 (81.7)
Myelopathy	10 (9.2)
Instability	17 (15.6)
Pseudarthrosis/failed fusion	18 (16.5)
Prior treatment	
Rt-sided approach	109 (100.0)
≥2 Prior ACDFs	35 (33.7)
≥3 cervical levels treated previously	42 (38.5)
Normal preoperative FEES	78 (71.6)
Preoperative FEEs abnormalities[b]	31 (28.4)
Swallow reflex delay	0
Clinically absent swallow reflex (<30 s)	0
Impaired pharyngeal constriction (right side)	5 (4.6)
Impaired pharyngeal constriction (left side)	0 (0.0)
Impaired tongue retraction	4 (3.7)
Impaired hyolaryngeal excursion	5 (4.6)
Impaired airway protection	1 (0.9)
Impaired sequential timing	5 (4.6)
Esophageal reflux	6 (5.5)
Impaired epiglottic inversion	1 (0.9)
Impaired anterior hyoid excursion	1 (0.9)
Impaired pharyngeal stripping wave	3 (2.8)
Baseline preoperative composite MDADI score[c]	92.6 (81.1, 97.9)
Existing complications[a]	
VCP, right side	4 (3.7)
Preoperative objective abnormality of swallowing[b]	6 (5.5)

ACDF, anterior cervical discectomy and fusion; BMI, body mass index; FEES, fiberoptic endoscopic evaluation of swallowing; MDADI, MD Anderson Dysphagia Inventory; VCP, vocal cord palsy.

[a]Several patients presented with more than 1 diagnosis and more than 1 existing FEES abnormality on preoperative evaluation.

[b]Preoperative objective abnormality of swallowing was defined as having either (1) a rating of ≥3 on the SPS, indicating at least mild impairment, or (2) a rating of ≥2 on the PAS, indicating any material entering airway during swallowing. If an abnormality was noted on preoperative FEES assessment, this did not necessarily rise to the level of preoperative objective abnormality of swallowing as defined by the SPS or PAS scale.

[c]Data are presented as median (IQR) for continuous, non-normally distributed measures.

functional FEES Performance Score decline, 45.0% (49/109) of patients demonstrated a decline in score by 2 weeks postoperatively. On linear regression, both number of cervical levels treated previously and at revision showed an association of FEES Performance Score decline with the increasing number of levels treated (R^2 = 0.0370, P = .045, and R^2 = 0.0879, P = .002, respectively) (**Supplementary Digital Content 2**, http://links.lww.com/NEU/D976). Similar to MDADI MCID, analysis of individual levels treated at revision did not show increased risk for decline in FEES Performance Score. There was a statistical trend toward the association of current alcohol use and FEES Performance Score decline at 2 weeks (P = .056). Finally, a linear regression was performed to determine the association of the changes in FEES Performance Scores and changes in MDADI scores. There was a significant association, but the correlation was not strong (R^2 = 0.0707, P = .005) (**Supplementary Digital Content 2**, http://links.lww.com/NEU/D976). No other risk factors were identified between those that had a Performance score decline and those that did not. Tables 4 and 5 present preoperative and postoperative MDADI scores for all 109 patients after revision ACDF with our 2-team approach. Box plots demonstrating the comparison of these data can be seen in **Supplementary Digital Content 3** (http://links.lww.com/NEU/D977).

DISCUSSION

Our study provides a comprehensive and updated assessment of the incidence and risk factors for voice and swallowing dysfunction in the early postoperative period for patients undergoing revision transcervical approach for ACDF using a 2-team approach. Our study is not only unique in that it is one of the very few studies in the literature to report this tandem exposure technique but it is also

TABLE 2. Risk Factors for New VCP Status Post-rACDF

Patient characteristic	No VCP (N = 98)	New VCP Post-rACDF (N = 7)	Total[b] (N = 105)	*P* value[d]
Sex				.70
Male	43 (43.9)	2 (28.6)	45 (42.9)	
Female	55 (56.1)	5 (71.4)	60 (57.1)	
Age at revision—y[a]	51.8 ± 9.3	53.1 ± 5.8	51.9 ± 9.1	.72
BMI	27.48 (5.05)	27.63 (3.92)	27.49 (4.97)	.94
BMI class				.43
BMI <30	69 (70.4)	4 (57.1)	73 (69.5)	
BMI ≥30 (obese)	29 (29.6)	3 (42.9)	32 (30.5)	
Smoker	17 (17.3)	2 (28.6)	19 (18.1)	.61
Alcohol use	53 (54.1)	3 (42.9)	56 (53.3)	.70
Operative time—min[a]	134.1 ± 37.3	142.7 ± 43.1	134.7 ± 37.5	.56
Time since last ACDF (mo)	39.5 (16-113)	33 (28-119)	38 (16-113)	.79
Previous Ops	1 (1, 2)	1 (1, 2)	1 (1, 2)	.70
Cervical levels treated previously	2 (2, 3)	3 (2, 3)	2 (2, 3)	.24
Cervical levels treated at revision	3 (2, 4)	4 (4,6)	3 (2, 4)	**.020**
Cervical levels treated at revision (categorized)				**.010**
≤3 levels	65 (66.3)	1 (14.3)	66 (62.9)	
≥4 levels	33 (33.7)	6 (85.7)	39 (37.1)	
Test results				
MDADI global score, preoperative	100 (80-100)	100 (80-100)	100 (80-100)	.68
MDADI composite score, preoperative	93.2 (82.1, 97.9)	91.6 (77.9, 97.9)	92.6 (81.1, 97.9)	.67
MDADI global score, postoperative	100 (80-100)	80 (80-100)	100 (80-100)	.31
MDADI composite score, postoperative	87.4 (73.7, 95.8)	76.8 (72.6, 95.8)	86.3 (73.7, 95.8)	.46
Functional abnormality of swallowing, preoperative	5 (5.1)	0 (0.0)	5 (4.8)	1.00
Functional abnormality of swallowing, postoperative[c]	25 (25.5)	4 (57.1)	29 (27.6)	.090
SPS score, preoperative				.60
1	63 (64.3)	6 (85.7)	69 (65.7)	
2	30 (30.6)	1 (14.3)	31 (29.5)	
3	5 (5.1)	0 (0.0)	5 (4.8)	
SPS score, postoperative				.32
1	37 (37.8)	1 (14.3)	38 (36.2)	
2	36 (36.7)	2 (28.6)	38 (36.2)	
3	22 (22.4)	4 (57.1)	26 (24.8)	
4	1 (1.0)	0 (0.0%)	1 (1.0)	

ACDF, anterior cervical discectomy and fusion; BMI, body mass index; MDADI, MD Anderson Dysphagia Inventory; rACDF, revision ACDF; SPS, Swallowing Performance Scale; VCP, vocal cord palsy.
[a]Data presented as mean ± SD or median (IQR) for continuous measures and n (%) for categorical measures.
[b]Four patients with existing baseline VCP were excluded from analysis.
[c]One patient's SPS score improved postoperatively.
[d]Bold *P* values <.05 are statistically significant; statistical significance for differences in means was tested using an independent *t*-test and medians with Wilcoxon rank-sum/Mann-Whitney *U* tests; statistical significance for differences in proportions was tested using the Fisher exact test.

TABLE 3. Summary of FEES Performance Score Decline and MDADI MCID by Risk Factors

		FEES performance score decline[d]			MDADI MCID[b]		
Variable	**Total**	**No**	**Yes**	***P* value[c]**	**No**	**Yes**	***P* value[c]**
No. of patients	109 (100.0)	60 (55.0)	49 (45.0)		68 (62.4)	41 (37.6)	
Sex				.44			1.00
Male	48 (44.0)	24 (40.0)	24 (49.0)		30 (44.1)	18 (43.9)	
Female	61 (56.0)	36 (60.0)	25 (51.0)		38 (55.9)	23 (56.1)	
Age at revision—y[a]	52.2 ± 9.2	51.5 ± 9.2	53.1 ± 9.1	.37	51.8 ± 8.6	52.9 ± 10.1	.54
Smoker	19 (17.4)	12 (20.0)	7 (14.3)	.46	15 (22.1)	4 (9.8)	.12
Alcohol use	37 (61.7)	21 (42.9)	58 (53.2)	.056	40 (58.8)	18 (43.9)	.17
Operative time—min[a]	134.7 ± 37.1	134.0 ± 31.4	135.5 ± 43.3	.83	136.6 ± 33.1	131.4 ± 43.0	.48
Age at revision, categorized				.34			.81
<60 y	87 (79.8)	50 (83.3)	37 (75.5)		55 (80.9)	32 (78.0)	
≥60 y	22 (20.2)	10 (16.7)	12 (24.5)		13 (19.1)	9 (22.0)	
Prior ACDFs				1.00			.84
1	72 (66.1)	40 (66.7)	32 (65.3)		44 (64.7)	28 (68.3)	
≥2	37 (33.9)	20 (33.3)	17 (34.7)		24 (35.3)	13 (31.7)	
Cervical levels treated previously	2 (2, 3)	2 (2, 3)	2 (2, 3)	**.045**[e]	2 (2, 3)	2 (2, 3)	.23
Cervical levels treated at revision	3 (2, 4)	3 (2, 4)	3 (3, 4)	**.002**[e]	3 (2, 4)	3 (3, 4)	.33
Individual cervical levels treated at revision							
C3–C4	23 (21.1)	12 (20.0)	11 (22.4)	.82	14 (20.6)	9 (22.0)	1.00
C4–C5	57 (52.3)	27 (45.0)	30 (61.2)	.12	33 (48.5)	24 (58.5)	.33
C5–C6	88 (80.7)	48 (80.0)	40 (81.6)	1.00	57 (83.8)	31 (75.6)	.32
C6–C7	68 (62.4)	36 (60.0)	32 (65.3)	.69	41 (60.3)	27 (65.9)	.68
C7–T1	11 (10.1)	5 (8.3)	6 (12.2)	.54	7 (10.3)	4 (9.8)	1.00

ACDF, anterior cervical discectomy and fusion; FEES, fiberoptic endoscopic evaluation of swallowing; MCID, minimum clinically important difference; MDADI, MD Anderson Dysphagia Inventory.

[a]Data are presented as mean ± SD for continuous measures and n (%) for categorical measures.

[b]MCID is decline in baseline and postoperative MDADI score by > 6.

[c]*P* values <.05 are statistically significant; statistical significance for differences in means was tested using an independent *t*-test; statistical significance for differences in proportions was tested using the Fisher exact test; statistical significance for differences in medians was tested using the Wilcoxon rank-sum test.

[d]FEES Performance Score Decline is defined as a worsened swallow rating on the SPS and/or PAS scale compared with preoperative assessment.

[e]Bold *P* values <.05 are statistically significant; statistical significance was tested using a linear regression.

the only study to our knowledge, aside from our previous 2018 report,[11] to demonstrate both early VCP and dysphagia rates by using functional and PROM tools simultaneously.

Vocal Cord Palsy

Vocal cord palsy after ACDF is believed to be due to injury to the RLN by direct sectioning or, perhaps more commonly, by indirect compression or stretch of the nerve during retraction. In our study, we found an early rate of new postoperative VCP to be 6.7% (7/105 patients) after rACDF. On univariable analysis, it is not surprising that the number of cervical levels with longer segment fusions (≥4 levels) was an independent predictor of new VCP after rACDF (P = .020 and .010, respectively). Reasons for this are multifactorial but are likely due to a combination of increased amount of tissue disturbance, inflammation/edema, manipulation, and retraction that are necessitated by a larger

TABLE 4. Selected Variables by Preoperative and Postoperative rACDF Surgery

Variable[a]	Preoperative rACDF (N = 109)	Postoperative rACDF (N = 109)	Preoperative and postoperative difference	*P* value[b]
MDADI composite score	92.6 (81.1, 97.9)	85.3 (73.7, 95.8)	−3.2 (−11.6, 1.1)	**<.001**
MDADI global score	100 (80, 100)	100 (80, 100)	0 (−20, 0)	**.003**
MDADI functional score	100 (84, 100)	88 (80, 100)	0 (−8, 0)	**.021**
MDADI emotional score	86.7 (80, 96.7)	86.7 (76.7, 93.3)	0 (−10, 3.3)	.26
MDADI physical score	100 (80, 100)	80 (65, 100)	−5 (−20, 0)	**<.001**
Rosenbeck Penetration-Aspiration Scale	1 (1, 1)	1 (1, 1)	0 (0, 0)	**.013**
SPS	1 (1, 2)	2 (1, 3)	0 (0, 1)	**<.001**

MDADI, MD Anderson Dysphagia Inventory; rACDF, revision anterior cervical discectomy and fusion; SPS, Swallowing Performance Scale.
[a]Data are presented as median (IQR) for continuous, non-normally distributed measures.
[b]Bold *P* values <.05 are bolded for statistical significance; statistical significance for differences in medians for the same population of patients pre-rACDF and post-rACDF was tested using the Wilcoxon signed-rank test for nonparametric, paired data.

exposure. Nevertheless, our early postoperative VCP incidence falls within previously reported ranges. In 2014, a systematic review reported by Tan et al[23] estimated the incidence of VCP due to RLN injury during ACDF to be between 0.2% and 24.2%. In 2017, Gokaslan et al,[24] from the AO Spine North America Clinical Research Network, conducted a multicenter study and reported the incidence of VCP after anterior cervical spine surgery to be 0.6%–2.9% between centers. However, none of these studies investigated a population of patients entirely undergoing rACDF. A more recent systematic review conducted by Erwood et al[25] in 2016 identified the rate of VCP from RLN injury to be 14.1% after rACDF. Our early rate of VCP at the 2-week follow-up after rACDF falls substantially below this estimated range. Furthermore, RLN injury or voice disturbance incidence is largely dependent on the timing of assessment during the postoperative course. Reported rates of persistent symptomatic VCP (defined as >12 months) vary in the literature from 0.33% to 2.5%.[26,27] It is important to note that most (6/7) patients with new VCPs in our cohort were temporary and were either improving or resolved by the 3-month follow-up. Long-segment fusion was the only variable found to be a risk factor for new, unilateral VCP, and this is not surprising as more extensive exposure and longer retraction times are required during these procedures, exposing the nerve to a higher risk of indirect injury.

Functional and Clinical Dysphagia

Although 45.0% (49/109) of patients had a functional FEES Performance Score decline in the early postoperative setting, only 37.6% (41/109) met MCID for reduction in subjective MDADI scores. Our incidence rates of dysphagia fall within the ranges of prior estimates ranging from 1.7% to 67%.[11,28-33] One study conducted by Smith-Hammond et al[34] used a similar functional measurement assessment of swallowing and reported a 47% incidence of abnormality on videofluoroscopic assessment 1 week

TABLE 5. Changes in MDADI Overall and Subscale Scores From Baseline to Postoperative Assessment and Percentage That met Minimal Clinically Important Differences

	Postoperative change in score (N = 109)			
MDADI score	Increased	Unchanged	Decreased	MCID[a] (N = 109)
Composite	28 (25.7)	12 (11.0)	69 (63.3)	41 (37.6)
Global	13 (11.9)	64 (58.7)	32 (29.4)	
Functional	16 (14.7)	51 (46.8)	42 (85.3)	
Emotional	35 (32.1)	32 (29.4)	42 (38.5)	
Physical	18 (16.5)	27 (24.8)	64 (58.7)	

MCID, minimum clinically important difference; MDADI, MD Anderson Dysphagia Inventory.
[a]MCID is decline in baseline and postoperative MDADI score by >6.

after primary ACDF. In a recent 2022 multicenter prospective study investigating 170 patients undergoing ACDF, Nguyen et al demonstrated that only baseline dysphagia and increasing operative times were the predictors of early dysphagia at 2 weeks postoperatively. Their overall incidence of clinical dysphagia by the Eating Assessment Tool (EAT-10) questionnaire was 45.3% at 2 weeks and declined to 15.3% at 24 weeks.[35] However, they only report 14 of the 170 patients to be reoperative ACDFs. Our study population is entirely representative of reoperative cases. In another study, Strohl et al retrospectively evaluated 80 patients who underwent rACDF with a similar 2-team approach (otolaryngologist and neurosurgeon). They reported an immediate postoperative dysphagia incidence of 52% (24-48 hours).[12] In both of these studies, the immediate and early 2-week incidence rates are similar to slightly higher than both the functional and PROMs found in our study (45.0% and 37.6%, respectively).

The results of our study indicate that the number of cervical levels treated previously and the number of cervical levels treated at revision showed an association with FEES Performance Score decline at 2 weeks after revision surgery. This was particularly significant at ≥4 levels. However, this association did not remain when analyzing clinically relevant rates of dysphagia at follow-up (MDADI MCID >6). This is an important distinction and underscores the importance of PROMs in quantifying the quality of life after rACDF. There are conflicting data in the literature regarding postoperative voice and swallowing dysfunction risk depending on the number of cervical levels treated. Several studies have found a significantly higher postoperative risk for swallowing and voice disturbances after multilevel ACDF compared with single-level ACDF.[29,30,33,36,37] Others have shown that multiple cervical levels were not related to the development of dysphonia or dysphagia.[35,38,39]

Substantial heterogeneity exists among previous studies regarding patient population, follow-up time, and assessment tools used during the postoperative course used to evaluate dysphagia. This inherently makes operative outcome comparison difficult and may limit the generalizability of these results. Nevertheless, our VCP and dysphagia incidence at 2 weeks not only underscores the value of a 2-team approach in a higher-risk patient population but also reveals a need for more standardized tools to evaluate VCP, dysphagia, and health-related quality of life outcomes in these patients.

Limitations

The main limitation of this study is the large number of patients enrolled but excluded from the final analysis, which may introduce selection bias into the study. While a larger cohort of patients with the control of confounders would have produced more robust conclusions, complications that result in dysphonia and dysphagia are often multifactorial, usually with low incidence and can be difficult to identify. Nevertheless, our primary objective was to describe voice and swallowing disturbance incidence and risk factors in this particular population. Despite these shortcomings, our study remains one of the largest known series in the literature for rACDF surgery with objective and subjective PRO measures of dysphonia and dysphagia. However, we do believe that simple, identifiable risk factors are considered here and may aid spine surgeons with patient selection. Although the MDADI questionnaire is a clinically useful dysphagia instrument, it was initially only validated in patients with head and neck cancer and is one of many used in assessing dysphagia after spinal surgery. Despite this, it was recently validated in a population of ACDF patients in 2020. Because our follow-up period was not carried out beyond 2 weeks for dysphagia, not all dysphagia outcomes were likely captured; however, we posit that most dysphagia complications (temporary or persistent) would have been present within this limited timeframe. Finally, because of multiple statistical testing, there is potential increase in Type 1 or false-positive error and the results must be interpreted with caution.

CONCLUSION

VCP is more likely to occur in long-segment rACDF but is often temporary and usually resolves by 3 months. Clinically relevant and functional rates of dysphagia approach 37% and 45%, respectively, at 2 weeks postoperatively after rACDF. Involvement of an experienced head and neck surgeon is safe and effective during rACDF.

Ethics

Institutional Review Board approval was obtained before this study (IRB-300010452).

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Disclosures

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Supplementary Digital Content 1. The MD Anderson Dysphagia Inventory Questionnaire cited with scoring interpretation.

Supplementary Digital Content 2. Scatter plots. Correlation between (A) the changes in FEES Performance Scores and MDADI scores (Pearson R^2 = 0.0707, P = .0052), (B) median number of prior cervical levels treated and FEES Scores (Pearson R^2 = 0.0370, P = .0451), and (C) median number of cervical levels treated at revision and FEES Scores (Pearson R^2 = 0.0879, P = .0017).

Supplementary Digital Content 3. Box plots. Distribution of preoperative and postoperative rACDF scores. Composite, global, functional, emotional, and physical subscores are displayed. Swallowing Performance Scale and Rosenbeck Penetration-Aspiration Scale scores are also demonstrated. Abbreviations: PREOPCOMPOSITE, preoperative composite score; POSTOPCOMPOSITE, postoperative composite score; PreOP_Global_Normalized, normalized preoperative Global subscore, Global_PosOp_Normalized, normalized postoperative Global subscore; F_normalized_PreOP, normalized preoperative functional subscore; F_normalized_PostOP, normalized postoperative functional subscore; E_normalized_PreOP, normalized preoperative emotional subscore; E_normalized_PostOP, normalized postoperative emotional subscore; P_normalized_PreOP, normalized preoperative physical subscore; P_normalized_PostOP, normalized postoperative physical subscore; SWALLOWINGPERFORMANCE_PRE, preoperative Swallowing Performance score; SWALLOWINGPERFORMANCE_POST, postoperative Swallowing Performance score; ROSENBECKASPIRATION_PREOP, preoperative Rosenbeck Aspiration

Scale score; ROSENBECKSCALE_POSTOP, postoperative Rosenbeck Aspiration Scale score.

COMMENTS

Dysphagia and dysphonia are common complications after anterior cervical discectomy and fusion (ACDF). However, the reported incidence in the existing studies varied widely, mainly caused by the diversity of outcome measurements. There are validated and unvalidated patient-reported, diet-based outcomes, or instrumental assessments for the evaluation of dysphagia and dysphonia. Inevitably, it would become ambiguous if these results of different measures were compared altogether. In this study, the authors presented the incidence by both subjective (MD Anderson Dysphagia Inventory [MDADI]) and objective (fiberoptic endoscopic assessment of swallowing [FEES] Performance Score for dysphagia and videolaryngostroboscopy [VLS] for vocal cord function) evaluations performed by a speech and language pathologist. As seen in the results, the subjective swallowing dysfunction rate (37.6%) was lower than the objective one (45.0%), and the possibility of evident vocal cord palsy was the lowest (6.7%). Such a high variation existed in a single study, not the mentioned all the different evaluations conducted by other tools in all the other published articles.

The target of this study was the patients who received revisionary ACDF using a 2-team approach (head and neck and neuro-surgeons). The authors found that the rates of new-onset early postoperative vocal cord palsy and functional or clinical dysphagia were within the previous-reported ranges after primary ACDF. Taking the wide ranges of the existing articles into account, such conclusions were not surprising. The lack of head-to-head comparison to those who received revision ACDF by neurosurgeon only masked the benefit of participation of head and neck surgeons. Some extreme conditions could also skew the results, given the variety of surgical characteristics (past operation times up to 4, and levels treated up to 6), which at least deserve a separate discussion.

This study nonetheless explained the importance of both subjective and objective evaluations about the incidence of dysphagia and vocal cord palsy. As for the potential benefit of 2-team approach for the revision ACDF, future studies about the direct comparison of 1-team approach may yield more evidence support the head and neck surgeons' involvement.

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This is a large cohort study of swallowing and vocal cord function in patients who underwent repeat ACDF. The authors show that using their multidisciplinary approach involving a head and neck surgeon for the approach, the rate of vocal cord palsies is quite low. Meanwhile, postoperative subjective and objective swallowing changes are common. These results are strengthened by the authors' standardized assessment of pharyngeal function pre- and postoperatively. An important follow-up questions raised by these findings is what is the long-term outcome in patients who experience vocal cord palsy or more commonly dysphagia.

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