Voice and swallowing outcomes following reoperative anterior cervical discectomy and fusion with a 2-team surgical approach

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OBJECTIVE Dysphagia and vocal cord palsy (VCP) are common complications after anterior cervical discectomy and fusion (ACDF). The reported incidence rates for dysphagia and VCP are variable. When videolaryngostroboscopy (VLS) is performed to assess vocal cord function after ACDF procedures, the incidence of VCP is reported to be as high as 22%. The incidence of dysphagia ranges widely, with estimates up to 71%. However, to the authors' knowledge, there are no prospective studies that demonstrate the rates of VCP and dysphagia for reoperative ACDF. This study aimed to investigate the incidence of voice and swallowing disturbances before and after reoperative ACDF using a 2-team operative approach with comprehensive pre- and postoperative assessment of swallowing, direct vocal cord visualization, and clinical neurosurgical outcomes.

METHODS A convenience sample of sequential patients who were identified as requiring reoperative ACDF by the senior spinal neurosurgeon at the University of Alabama at Birmingham were enrolled in a prospective, nonrandomized study during the period from May 2010 until July 2014. Sixty-seven patients undergoing revision ACDF were enrolled using a 2-team approach with neurosurgery and otolaryngology. Dysphagia was assessed both preoperatively and postoperatively using the MD Anderson Dysphagia Inventory (MDADI) and fiberoptic endoscopic evaluation of swallowing (FEES), whereas VCP was assessed using direct visualization with VLS.

RESULTS Five patients (7.5%) developed a new postoperative temporary VCP after reoperative ACDF. All of these cases resolved by 2 months postoperatively. There were no new instances of permanent VCP. Twenty-five patients had a new swallowing disturbance detected on FEES compared with their baseline assessment, with most being mild and requiring no intervention. Nearly 60% of patients showed a decrease in their postoperative MDADI scores, particularly within the physical subset.

CONCLUSIONS A 2-team approach to reoperative ACDF was safe and effective, with no new cases of VCP on postoperative VLS. Dysphagia rates as assessed through the MDADI scale and FEES were consistent with other published reports.

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KEY WORDS reoperative ACDF; vocal cord paralysis; dysphasia; otolaryngologist; cervical

ABBREVIATIONS ACDF = anterior cervical discectomy and fusion; FEES = fiberoptic endoscopic evaluation of swallowing; MDADI = MD Anderson Dysphagia Inventory; RLN = recurrent laryngeal nerve; SLP = speech and language pathologist; UAB = University of Alabama at Birmingham; VCP = vocal cord palsy; VLS = videolaryngostroboscopy.

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DYSPHAGIA and vocal cord palsy (VCP) are common complications after anterior cervical discectomy and fusion (ACDF). The reported incidence for both dysphagia and VCP varies in the literature according to the time the assessment is performed after surgery and the method and completeness of the evaluation. When assessment is performed with questionnaires or objective measurement, the incidence of dysphagia ranges widely, from 17.5% to 71%.^{1,5,8,11,15,25–28,30–32,34,35,37,38,48,49}

Most published studies on the complications of ACDF report the incidence of dysphonia rather than VCP, the latter of which requires the use of endoscopic confirmation such as videolaryngostroboscopy (VLS). Dysphonia is reported in approximately 1%–70% of patients after ACDF.^{6,9,20,33,43} Multilevel ACDF and reoperative ACDF procedures are recognized as important risk factors for the development of postoperative dysphagia and VCP.^{27,31,38,44}

To our knowledge, no prospective study has been performed to examine the rate of VCP or recurrent laryngeal nerve (RLN) injury in reoperative ACDF surgeries. The frequency of RLN palsy has been suggested to range from 1% to 11% for primary operations. The first attempt to assess the rate of RLN palsy in reoperative ACDF was performed by Erwood et al., using dysphagia as a marker of RLN palsy. In this study, the rate of dysfunction was estimated at approximately 14.1%, which suggested that patients undergoing reoperative ACDF were more susceptible to RLN injury.¹⁶ In addition, the literature to date does not assess the usefulness of a 2-team surgical approach, with exposure done by otolaryngologists for reoperative surgeries.

This study aimed to investigate the incidence of voice and swallowing disturbance before and after reoperative ACDF procedures using a 2-team operative approach with comprehensive pre- and postoperative assessment of swallowing, direct vocal cord visualization, and clinical neurosurgical outcomes.

Methods

A convenience sample of sequential patients, who were identified by the senior spinal neurosurgeon at the University of Alabama at Birmingham (UAB) as requiring reoperative ACDF, were enrolled in a prospective, non-randomized study during the period from May 2010 until July 2014. All enrolled patients had undergone 1 or more ACDF procedures and consented to participate in the multidisciplinary study, which was approved by the UAB institutional review board. The patients were selected as a convenience sample rather than as a random, or probability, sample due to ease of enrollment and patient availability.¹⁷

Surgical Protocols

Information was collected outlining the nature of previous surgery, including the side of approach, cervical spine levels previously operated on, number of previous surgeries, time since the most recent surgery, current diagnosis, and patient demographic data.

Revision Surgery Using a 2-Team Approach

Sixty-seven patients undergoing revision ACDF were

enrolled. In all instances, the previous surgery was via the right side and the study surgery was conducted via a reoperative right anterior transcervical approach. Dissection was performed through scar by the double team of surgeons. The head and neck surgeon obtained exposure to the necessary spinal levels through the soft tissues of the neck. The neurosurgeon then completed the revision ACDF surgical procedure and closed. The number of cervical levels approached was recorded for each patient, as was the type and number of interbody fusion substrate and internal fixation devices.

Assessment of Swallowing

A senior certified speech and language pathologist (SLP) performed the assessment of all patients preoperatively and again at 2 weeks postoperatively.

The SLP assessment consisted of subjective and objective aspects. The subjective component was collected through completion of the MD Anderson Dysphagia Inventory (MDADI). In this validated, self-administered questionnaire, the patient responds to 20 statements with 1 of 5 options: strongly agree, agree, no opinion, disagree, or strongly disagree. These are then quantified and used to generate a score from 20 to 100 under the domains emotional, functional, physical, and general, as described by Chen et al.¹⁰

Fiberoptic endoscopic evaluation of swallowing (FEES) was used pre- and postoperatively to provide objective evidence of dysphagia. Participants were administered thin liquids, thickened liquids, puree, and solid food. Results were recorded according to the Penetration-Aspiration scale,³⁹ the swallowing performance scale,⁴⁰ and direct Pharyngeal Phase assessment. This was documented on a UAB FEES data sheet for individual patients, and later tabulated using a Microsoft Excel version 14.4.6 spreadsheet. A new objective abnormality was declared for patients with any abnormality that was not present on the preoperative FEES.

Assessment of Vocal Cord Paralysis

Objective assessment of vocal cord function was completed using pre- and postoperative VLS. New VCP was defined as a patient with a normal preoperative VLS who was found to have developed either total paralysis or significantly reduced motion of a vocal cord on postoperative VLS.

Patients with new postoperative findings of vocal cord or swallowing dysfunction were followed until resolution. The study protocol was reviewed and approved by the UAB institutional review board prior to the enrollment of any patient.

Statistical Analysis

Frequency distributions of demographic characteristics, pathology, prior ACDF, VCP, and FEES abnormalities were obtained. Age at revision surgery, time since initial surgery, and MDADI scores were assessed as continuous variables with mean differences evaluated according to development of VCP using Student's independent t-test and a nonparametric Mann-Whitney U-test, where

appropriate. Differences in proportions for the categorical variables of sex, diagnosis, presence of VCP, number of previous surgeries, MDADI scores expressed as proportions, FEES scales, number of cervical levels fused, and objective abnormalities of swallowing were evaluated using Fisher's exact test.

Comparisons of differences in pre- and post-ACDF mean MDADI scores, FEES scales, and number of cervical levels fused in patients were tested using the Wilcoxon signed-rank test for paired data. Differences in the proportion of pre- and postoperative objective abnormality of swallowing function were evaluated using McNemar's test for paired data.

An alpha level of 0.05 was considered statistically significant. Analyses were performed using SAS version 9.4 (SAS Institute, Inc.).

Results

A total of 67 consecutive patients were enrolled in the study. All 67 patients had complete preoperative and postoperative SLP assessments. The most common presenting pathology was radiculopathy (62.7%), followed by failure of internal fixation and/or fusion (16.4%), and myelopathy (16.4%). The average age of patients was 53 years (range 31–84 years), and the sex ratio was roughly equal (men 48%, women 52%) among patients. Details of pathology, prior surgery, and existing complications are reported in Table 1. Two patients (3.0%) had a preexisting VCP affecting the right vocal cord. Nine patients (13.4%) had an objective abnormality of swallowing detected on preoperative FEES. The swallowing impairment was mild to moderate and was most commonly stasis of fluids ($n = 7$). Three patients required modification to their diet or therapeutic swallowing precautions preoperatively. Postoperatively, 3 of these 9 patients improved sufficiently to have no further objective evidence of a swallowing abnormality.

Five patients (7.5%) developed a new postoperative temporary VCP after reoperative ACDF. All of these cases resolved by 2 months postoperatively. There were no new instances of permanent VCP. The 2 patients with preoperative VCP continued to have unilateral VCP postoperatively. Bivariate analysis was conducted to identify potential predictors for the development of postoperative temporary VCP. Postoperative objective abnormality of swallowing and postoperative FEES performance scale showed statistically significant differences by new onset of VCP ($p = 0.02$ and $p = 0.01$, respectively). In addition, a relationship between preoperative MDADI scores and new onset of VCP exhibited borderline statistical significance ($p = 0.05$). However, sex, age at ACDF revision surgery, time since ACDF revision surgery, multilevel surgery, multiple prior surgeries, or institution where prior surgery was performed did not show any statistically significant association with new onset of VCP (Table 2).

Almost half of the study population (44.8%) had swallowing abnormalities detected on postoperative FEES. Seven of these patients had a preexisting abnormality; 25 patients (76.7%) had a new swallowing disturbance detected on FEES compared with their baseline assessment. Of these patients with objective evidence of swallowing

TABLE 1. Baseline characteristics of the study population

Variable	No. of Patients (%)
No. of patients	67 (100)
Demographic data	
Male sex	32 (47.8)
Age >60 yrs at revision op	15 (22.4)
Diagnosis	
Radiculopathy	42 (62.7)
Myelopathy	11 (16.4)
Instability w/ failed fusion	11 (16.4)
Pseudarthrosis	7 (10.5)
Prior treatment	
Rt-sided approach	67 (100.0)
≥2 prior ACDF ops	24 (35.8)
≥3 cervical levels treated previously	36 (53.7)
Existing complications	
VCP	2 (3.0)
FEES abnormalities	9 (13.4)

disturbance, most cases were mild and required no intervention ($n = 20$, 29.9%), but a sizable number did require therapeutic swallowing precautions ($n = 8$, 11.9%) and 2 patients had aspiration requiring modification of their diet. Both of these patients also had a new VCP detected on VLS and returned to a normal diet upon last review at 2 months postoperatively when their VCP recovered. Bivariate analysis of risk factors for the development of postoperative complications (VCP, FEES decline, and MDADI decline) failed to detect any significant associations (Table 3).

The mean MDADI scores calculated at baseline and postoperatively are shown in Table 4. There was a statistically significant difference in pre-ACDF surgery and post-ACDF composite MDADI scores, with the physical MDADI subscale pre- and postoperative difference ($p < 0.0001$) emerging as the greatest domain contributor to the statistically significant composite score ($p = 0.001$). The changes from baseline to postoperative assessment in FEES performance ratings and number of cervical levels fused also tested as statistically significant ($p < 0.0001$ for each of these pre- and postoperative differences).

Changes in mean MDADI scores from baseline to postoperative assessment for MDADI subscales are documented in Table 5. Comparisons of overall and subscale MDADI scores (categorized as increased, decreased, or unchanged after post-ACDF) showed that nearly 60% of patients demonstrated a decline in their overall postoperative MDADI scores (Table 6). Although the highest proportion of global subscale scores remained unchanged (59.7%), the leading proportions of remaining subscales indicated that functional, emotional, and physical MDADI scores exhibited decreases postoperatively from their baseline assessments (43.3%, 37.3%, and 58.2%, respectively).

When analysis of potential risk factors associated with a decline in overall MDADI score was performed (Table 3), the only variable that approached statistical significance was patient age younger than 60 years ($p = 0.08$);

TABLE 2. Risk factors by VCP status

Patient Characteristic	Total	No VCP	VCP Post-ACDF Surgery	p Value*
No. of patients	67	62	5	
Male sex, no. (%)	32 (47.8)	30 (48.4)	2 (40.0)	1.00
Age in yrs at revision op, mean $\pm$ SD	52.2 $\pm$ 10.1	52.0 $\pm$ 9.9	55.0 $\pm$ 13.1	0.53
Age >60 yrs at revision op, no. (%)	52 (77.6)	48 (77.4)	4 (80.0)	1.00
Time in yrs since revision op, mean $\pm$ SD	4.5 $\pm$ 4.8	4.5 $\pm$ 4.8	5.2 $\pm$ 5.5	0.75
Previous ops, no. (%)				0.18
1	43 (64.2)	41 (66.1)	2 (40.0)	
2	16 (23.9)	15 (24.2)	1 (20.0)	
3	7 (10.4)	5 (8.1)	2 (40.0)	
4	1 (1.5)	1 (1.6)	0 (0.0)	
Test results				
MDADI global score, preop, mean $\pm$ SD	88.3 $\pm$ 12.3	89.2 $\pm$ 11.8	78.2 $\pm$ 14.9	0.05
MDADI global score, postop, mean $\pm$ SD	84.2 $\pm$ 12.2	84.7 $\pm$ 12.2	78.9 $\pm$ 11.2	0.31
Objective abnormality of swallowing, preop, no. (%)	10 (14.9)	8 (12.9)	2 (40.0)	0.16
Objective abnormality of swallowing, postop, no. (%)	30 (44.8)	25 (40.3)	5 (100.0)	0.02
FEES performance score, preop, no. (%)				0.13
1	58 (86.5)	55 (88.7)	3 (60.0)	
2	6 (9.0)	5 (8.1)	1 (20.0)	
3	3 (4.5)	2 (3.2)	1 (20.0)	
FEES performance score, postop, no. (%)				0.01
1	37 (55.2)	37 (59.7)	0 (0.0)	
2	20 (29.9)	17 (27.4)	3 (60.0)	
3	8 (11.9)	7 (11.3)	1 (20.0)	
4	1 (1.5)	1 (1.6)	0 (0.0)	
5	1 (1.5)	0 (0.0)	1 (20.0)	
Cervical levels previously treated, no. (%)				0.20
2	31 (46.2)	30 (48.4)	1 (20.0)	
3	26 (38.8)	24 (38.6)	2 (40.0)	
4	5 (7.5)	4 (6.5)	1 (20.0)	
5	5 (7.5)	4 (6.5)	1 (20.0)	

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TABLE 2. Risk factors by VCP status

Patient Characteristic	Total	No VCP	VCP Post-ACDF Surgery	p Value*
Cervical levels treated at UAB, no. (%)				0.11
2	8 (11.9)	8 (12.9)	0 (0.0)	
3	26 (38.8)	25 (40.3)	1 (20.0)	
4	19 (28.4)	18 (29.0)	1 (20.0)	
5	9 (13.4)	8 (12.9)	1 (20.0)	
6	5 (7.5)	3 (4.9)	2 (40.0)	

* p values < 0.05 are statistically significant; statistical significance for differences in means was tested using an independent t-test and Wilcoxon rank-sum/Mann-Whitney U-tests; statistical significance for differences in proportions was tested using Fisher's exact test.

85% of patients with declines in MDADI scores were in this age group.

Associations between single versus multiple prior ACDF surgeries and a range of potential risk factors were also evaluated. Table 7 presents the results of the bivariate analysis that indicates those risk factors that were associated with whether patients had undergone multiple prior ACDF surgeries. Time since ACDF initial surgery, number of cervical levels treated before revision ACDF at UAB, and radiculopathy diagnosis, as well as baseline assessments of FEES, objective abnormality of swallowing, and 100-point MDADI global score all had statistically significant associations with single versus multiple prior ACDF surgeries. Postoperative risk factors were not related to multiple prior ACDF surgeries.

All 67 patients met clinical and radiographic postoperative assessment milestones, which included follow-up clinic visits, wound checks, and plain films to assess the fusion constructs. One patient had a non-VCP, nonswallowing complication, which was a postoperative hematoma treated effectively on the first postoperative day. Sixty of 67 patients (89.5%) met postoperative milestones at 12 months (7 patients were lost to follow-up). Of those lost to follow-up, 2 patients had dysphagia at 2 months. The length of hospital stay ranged from 1 to 4 days. Discharge typically depended on the patient's ability to swallow effectively, with therapeutic swallowing modifications and/or dietary modifications.

Discussion

The etiology of VCP following ACDF relates to injury to the RLN, whereas the etiology of dysphagia is less certain. VCP may be due to sectioning or retraction injury of the RLN, retraction of the esophagus with reduced perfusion,²¹ direct pharyngeal or esophageal pressure,²² hypoglossal nerve injury,³⁵ or alteration in C2–7 angle.^{36,47} Injury to the superior laryngeal nerve (particularly in high approaches) is also a cited cause, and although not well documented in the ACDF literature, is a well-known cause

TABLE 3. Summary of postoperative complications by risk factors

Variable	Total	VCP			FEES Decline			MDADI Decline		
		No	Yes	p Value	No	Yes	p Value	No	Yes	p Value
No. of patients	67	62	5		42	25		27	40	
Sex, no (%)				1.00			0.33			0.58
Female	35 (52.2)	32 (51.6)	3 (60.0)		20 (47.6)	15 (60.0)		13 (48.2)	22 (55.0)	
Male	32 (47.8)	30 (48.4)	2 (40.0)		22 (52.4)	10 (40.0)		14 (51.8)	18 (45.0)	
Age in yrs at revision op, no. (%)				1.00			0.81			0.08
<60	52 (77.6)	48 (77.4)	4 (80.0)		33 (78.6)	19 (76.0)		18 (66.7)	34 (85.0)	
≥60	15 (22.4)	14 (22.6)	1 (20.0)		9 (21.4)	6 (24.0)		9 (33.3)	6 (15.0)	
Prior ACDF ops, no. (%)				0.34			0.58			0.73
1	43 (64.2)	41 (66.1)	2 (40.0)		28 (66.7)	15 (60.0)		18 (66.7)	25 (62.5)	
≥2	24 (35.8)	21 (33.9)	3 (60.0)		14 (33.3)	10 (40.0)		9 (33.3)	15 (37.5)	
Cervical levels treated previously, no. (%)				0.36			0.07			0.81
2	31 (46.3)	30 (48.4)	1 (20.0)		23 (54.8)	8 (32.0)		12 (44.4)	19 (47.5)	
≥3	36 (53.7)	32 (51.6)	4 (80.0)		19 (45.2)	17 (68.0)		15 (55.6)	21 (52.5)	
Cervical levels treated at UAB, no. (%)				1.00			0.99			1.00
2	8 (11.9)	8 (12.9)	0 (0.0)		5 (11.9)	3 (12.0)		3 (11.1)	5 (12.5)	
≥3	59 (88.1)	54 (87.1)	5 (100.0)		37 (88.1)	22 (88.0)		24 (88.9)	35 (87.5)	

of dysphagia following oncological surgery of the neck. During reoperative ACDF, the presence of scar tissue after prior ACDF often distorts the normal anatomy, makes exposure and retraction more difficult, and increases the risk of RLN injury during revision.

To our knowledge, this prospective observational study provides the first description of a 2-team surgical approach for reoperative ACDF. It is the only example of a protocol that includes standardized fiberoptic inspection of vocal cord function preoperatively and postoperatively in an exclusively reoperative setting. Similarly, it provides the most comprehensive assessment of the incidence of postoperative dysphagia following reoperative ACDF.

New-onset dysphagia following reoperative ACDF was defined as a reduction in the overall MDADI score between the baseline and postoperative measures. Nearly 60% of patients in this study reported a subjective decline

using this measure. Fifty-eight percent of patients reported a decline in the physical subset. This method of reporting using a questionnaire is likely to capture a greater number of patients than those reported in retrospective reviews. Retrospective reviews form the bulk of the literature reporting on the incidence of dysphagia after ACDF. They typically report the incidence of dysphagia to be in the range of 1.25%–13.3%.^{2,4,7,12–14,18,19,23,24,29,35,41–44,46,47}

Prospective analyses featuring questionnaires report a higher rate of dysphagia, ranging from 20% to 71%.^{5,15,25–28,30–32,34,35,37,38,48,49} These prospective studies are comparable to the present study. Using a questionnaire, Lee et al.²⁷ reported the incidence of subjective dysphagia at multiple time points during the 2 years after surgery. In the initial month after surgery, they reported an incidence of dysphagia of 54%. For reoperative ACDF cases, the incidence of dysphagia was 62%. At 2 years after surgery, they

TABLE 4. Selected variables by pre- and post-ACDF surgery differences

Variable	Pre-ACDF Op	Post-ACDF Op	Preop/Postop Difference	p Value*
No. of patients	67	67		
MDADI composite score	88.3 ± 12.3	84.2 ± 12.2	4.1 ± 10.7	0.001
MDADI global score	89.5 ± 16.1	86.1 ± 14.9	3.4 ± 15.5	0.11
MDADI functional score	89.3 ± 10.8	86.9 ± 11.5	2.4 ± 9.6	0.07
MDADI emotional score	85.5 ± 14.3	84.5 ± 12.1	1.0 ± 12.6	0.27
MDADI physical score	88.9 ± 14.1	79.5 ± 17.6	9.4 ± 15.9	<0.0001
FEES–Rosenbek Penetration-Aspiration Scale	1.0 ± 0.0	1.1 ± 0.4	–0.1 ± 0.4	0.13
FEES performance scale	1.2 ± 0.5	1.7 ± 0.9	–0.5 ± 0.9	<0.0001
No. of cervical levels fused	2.8 ± 0.9	3.7 ± 1.1	–0.9 ± 0.9	<0.0001

Values are mean ± SD unless otherwise noted.

* p values < 0.05 are statistically significant; statistical significance for differences in means was tested using the Wilcoxon signed-rank test for paired data; statistical significance for differences in proportions was tested using McNemar's test for paired data.

TABLE 5. MDADI scores at baseline and postoperatively across each MDADI domain

MDADI Score	Global	Functional	Emotional	Physical
Baseline	90 ± 16.1	89.3 ± 10.9	85.5 ± 14.3	88.9 ± 14.1
Postop	86.1 ± 14.9	86.9 ± 11.5	84.5 ± 12.1	79.5 ± 17.6
Decline in score	3.4 ± 15.5	2.4 ± 9.6	1.0 ± 12.6	9.4 ± 15.9

Values are mean ± SD.

described an incidence of dysphagia of 27.7% for reoperative ACDF cases compared with a dysphagia rate of 11.3% for patients treated with a primary ACDF procedure.

Only 1 prior study has reported using the MDADI assessment following ACDF surgery. Mendoza et al.³² reported the use of MDADI to assess dysphagia in a group of patients undergoing primary ACDF procedures. They used an MDADI score < 85 to arbitrarily define dysphagia. They reported better mean MDADI preoperative scores than the mean MDADI preoperative scores in our series of patients who underwent reoperative ACDF surgeries (93.8; SD ± 12.0 vs 88.0; SD ± 12, respectively). However, the decline in mean MDADI scores to 67.7 (SD ± 11.4) on postoperative Day 1 reported by Mendoza et al. was greater than the decline we identified in our series at 2 weeks postoperatively (mean MDADI score 84.0; SD ± 12.0). At 6 months postoperatively, mean MDADI scores had improved to > 85 for all patients in their series.

In the present study, objective evidence of new swallowing dysfunction was observed in 25 patients (37%) on postoperative FEES 2 weeks after ACDF. This finding was lower for patients 60 years or older, of whom 24.0% had new FEES abnormalities compared with 76.0% in those younger than 60 years ($p = 0.81$). Although our results were not statistically significant, similar findings have been reported. Smith-Hammond et al.⁴⁵ reported a 47% incidence of abnormality on videofluoroscopic examination 1 week after primary ACDF. This incidence had reduced to 13% by 2 months postoperatively. Smith-Hammond et al. reported that age older than 60 years was associated with radiographic evidence of dysphagia ($p < 0.01$). It should be noted that the study by Smith-Hammond et al. included primary ACDF surgical cases only.

Arguably, the most important goal of this study was to establish a rate of VCP in reoperative ACDF surgery through a comprehensive, prospective study. The best estimate of the rate of VCP in the current literature is from a recent meta-analysis by Erwood et al., who reported an incidence of 14.1% of permanent VCP. This meta-analysis used dysphagia as a surrogate for injury to the RLN, which was due to a paucity of publications that reported routine direct inspection of the vocal cords. In that study the authors included a total of 238 patients in their analysis and concluded that the estimate of 14.1% for RLN palsy in reoperative ACDF surgery was greater than any estimated rate for primary procedures.¹⁶ Although this provides a useful estimate, the limitations of the meta-analysis for estimating the rate of VCP are obvious. Without direct visualization of the vocal cords, accurate assessments of RLN injury and dysphonia are not attainable.

TABLE 6. Changes in MDADI overall and subscale scores from baseline to postoperative assessment

MDADI Score	Postop Change in Score		
	Increased	Unchanged	Decreased
Overall	17 (25.4)	10 (14.9)	40 (59.7)
Global	7 (10.5)	40 (59.7)	20 (29.9)
Functional	12 (17.9)	26 (38.8)	29 (43.3)
Emotional	18 (26.9)	24 (35.8)	25 (37.3)
Physical	9 (13.4)	19 (28.4)	39 (58.2)

Values are number (%) of patients.

The use of routine pre- and postoperative direct inspection of vocal cord function is well established as the gold standard to define the incidence of postoperative VCP. The present study used pre- and postoperative assessment of vocal cord function through direct inspection using a videolaryngoscope. Using this comprehensive approach, we report an overall new incidence of permanent VCP of 0.0% and temporary VCP of 7.5% in the 67 patients tested with reoperative ACDF. As mentioned previously, the current literature documents an estimate of RLN injury of 14.1%.¹⁶ Therefore, the major finding of this study is that when a 2-team surgical approach is applied to patients undergoing reoperative ACDF (those typically described as being at increased risk for VCP complications), these patients do not develop VCP complications at an increased rate. This finding supports the notion that a 2-team approach using an experienced head and neck surgeon can provide safe transcervical access for reoperative ACDF in patients at high risk for VCP. Neurological, clinical, and radiographic outcomes in this limited series at 3 and 12 months are consistent with other published reports.

An explanation for how the head and neck surgeon may be able to provide safer access to the cervical spine, despite having never performed an ACDF procedure, probably relates to cross training achieved through other surgeries that otolaryngologists perform in the anterior neck. The relevant operations include thyroid surgery, where most surgeons advocate the routine identification of the RLN and there is an emerging trend toward the routine identification of the superior laryngeal nerve.³ Neck dissections, laryngectomy, submandibular gland excision, open repair of Zenker's diverticulum, and drainage of deep neck infections also prepare the head and neck surgeon for reoperative transcervical exposures of ACDF procedures. Patient factors, including prior surgery, radiation, and tumor, are frequently encountered by the head and neck surgeon and provide experience with negotiating distorted anatomy in the neck anterior to the cervical spine. In addition, otolaryngologists are accustomed to working side by side with neurosurgeons to provide access to the skull base for anterior fossa, sinus, and pituitary pathology and for petrous and cerebellopontine pathology.

This prospective observational study has some limitations. The limited duration of postoperative SLP follow-up in this series did not allow us to detect the likely improvement in postoperative dysphagia reported in most studies when late SLP assessment is accomplished following sur-

TABLE 7. Risk factors by single versus multiple prior ACDF surgeries

Variable	Total	Single Prior ACDF Op	Multiple Prior ACDF Ops	p Value*
No. of patients	67	43	24	
Male sex, no. (%)	32 (47.8)	22 (51.2)	10 (41.7)	0.46
Rt-sided approach, no. (%)	67 (100.0)	43 (100.0)	24 (100.0)	—
Age in yrs at revision op, mean $\pm$ SD	52.2 $\pm$ 10.1	52.2 $\pm$ 10.5	52.3 $\pm$ 9.6	0.95
Age >60 yrs at revision op, no. (%)	15 (22.4)	10 (23.3)	5 (20.8)	0.82
Time in yrs since revision op, mean $\pm$ SD	4.5 $\pm$ 7.8	5.4 $\pm$ 5.3	2.8 $\pm$ 3.2	0.02
Diagnosis, no. (%)				
Radiculopathy	42 (62.7)	31 (72.1)	11 (45.8)	0.03
Myelopathy	11 (16.4)	6 (14.0)	5 (20.8)	0.51
Instability w/ failed fusion	11 (16.4)	5 (11.6)	6 (25.0)	0.18
Pseudarthrosis	7 (10.5)	4 (9.3)	3 (12.5)	0.70
Existing VCP, no. (%)	2 (3.0)	0 (0.0)	2 (8.3)	0.13
MDADI global score, preop = 100, no. (%)	42 (62.7)	31 (72.1)	11 (45.8)	0.03
MDADI global score, postop = 100, no. (%)	29 (43.3)	21 (48.8)	8 (33.3)	0.22
Objective abnormality of swallowing, preop, no. (%)	10 (14.9)	3 (7.0)	7 (29.2)	0.03
Objective abnormality of swallowing, postop, no. (%)	30 (44.8)	16 (37.2)	14 (58.3)	0.10
FEES performance score, preop, no. (%)				0.005
1	58 (86.5)	41 (95.4)	17 (70.8)	
2	6 (9.0)	2 (4.6)	4 (16.7)	
3	3 (4.5)	0 (0.0)	3 (12.5)	
FEES performance score, postop, no. (%)				0.13
1	37 (55.2)	27 (62.8)	10 (41.7)	
2	20 (29.9)	12 (27.9)	8 (33.3)	
3	8 (11.9)	3 (7.0)	5 (20.8)	
4	1 (1.5)	0 (0.0)	1 (4.2)	
5	1 (1.5)	1 (2.3)	0 (0.0)	
Cervical levels previously treated, no. (%)				<0.0001
2	31 (46.2)	28 (65.1)	3 (12.5)	
3	26 (38.8)	13 (30.2)	13 (54.2)	
4	5 (7.5)	2 (4.7)	3 (12.5)	
5	5 (7.5)	0 (0.0)	5 (20.8)	
Cervical levels treated at UAB, no. (%)				0.70
2	8 (11.9)	6 (13.9)	2 (8.4)	
3	26 (38.8)	18 (41.9)	8 (33.3)	
4	19 (28.4)	11 (25.6)	8 (33.3)	
5	9 (13.4)	6 (13.9)	3 (12.5)	
6	5 (7.5)	2 (4.7)	3 (12.5)	

* p values < 0.05 are statistically significant.

gery. This makes comparisons between series that address postoperative dysphagia difficult. The lack of a randomized comparative control arm also prevented a direct comparison between voice and swallowing outcomes when a head and neck surgeon performs the reoperative transcervical exposure compared with the spinal neurosurgeon alone. The decision not to randomly assign patients was deliberate and was influenced by preliminary observations of favorable outcomes for patients similarly managed before initiating the current study.

In summary, this study provides preliminary evidence

to support the use of a 2-team surgical approach using a head and neck surgeon to perform the reoperative transcervical exposure to the anterior cervical spine during reoperative ACDF. This is a procedure and a group of patients typically described as being at high risk for postoperative VCP and dysphagia.

Conclusions

A 2-team approach using a head and neck surgeon to provide reoperative transcervical exposure to the anterior cervical spine during reoperative ACDF seems to be safe

and effective. Patients typically described as being at high risk for voice and dysphagia complications of reoperative ACDF procedures seem to benefit by a neurosurgery-otolaryngology surgical team approach.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Erwood, Walters, Connolly, Gordon, Carroll, Agee, Hadley. Acquisition of data: all authors. Analysis and interpretation of data: Erwood, Walters, Connolly, Gordon, Carroll, Agee, Hadley. Drafting the article: Erwood, Walters, Connolly, Gordon, Carroll, Hadley. Critically revising the article: Erwood, Walters, Connolly, Gordon, Carroll, Agee, Hadley. Reviewed submitted version of manuscript: Erwood, Walters, Connolly, Gordon, Carroll, Agee, Hadley. Approved the final version of the manuscript on behalf of all authors: Erwood. Statistical analysis: Erwood, Walters, Connolly, Gordon, Carroll, Agee, Hadley. Administrative/technical/material support: Erwood, Walters, Connolly, Gordon, Carroll. Study supervision: Erwood, Walters, Connolly, Gordon, Carroll, Hadley.

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