Dysphagia
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ORIGINAL ARTICLE

Dysphagia Following Anterior Cervical Discectomy and Fusion: A PearlDiver Analysis of Incidence, Risk Factors, and Interventions

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Abstract

Anterior cervical discectomy and fusion (ACDF) is a well-established surgical procedure, with wide variation in reported postoperative dysphagia rates (1–79%). No standardized guidelines exist for screening, diagnosis, and treatment of postoperative ACDF dysphagia. The goal of the current study is to utilize a large database of US healthcare insurance claims to investigate incidence of dysphagia post-ACDF as well as risk factors for dysphagia and interventions performed in a large patient cohort. PearlDiver database was used to identify patients without preoperative dysphagia undergoing ACDF between 2010 and 2022 and create cohorts of patients with and without postoperative ACDF dysphagia. International Classification of Disease version 9 and 10 (ICD-9 and ICD-10), and Current Procedural Terminology (CPT) codes were used to retrieve patient records. The two cohorts were compared in terms of age, gender, comorbidities, prior neck surgery, postoperative vocal fold paralysis, and dysphagia related interventions. OR with 95% CI were calculated, stratifying by various risk factors. Prevalence of various postoperative diagnoses and interventions were calculated. Of 618,170 patients undergoing primary ACDF from 2010 to 2022, 88,899 (14.4%) developed postoperative dysphagia. Females, smokers, diabetics, and obese patients had higher odds of developing post ACDF dysphagia (OR 1.14, 2.51, 2.18, 2.50 respectively). 3% of patients with post ACDF dysphagia had new postoperative vocal fold motion impairment (VFMI) versus 0.3% without dysphagia (OR 8.69). Within the dysphagia cohort,14.9% underwent laryngoscopy, 19.0% underwent MBSS, 0.80% underwent FEES, and 5.2% received swallow therapy. Dysphagia is commonly diagnosed after ACDF, with females, smokers, diabetics, and obese patients having the highest odds of diagnosis. Yet, a low percentage of patients are being referred for evaluation or treatment. Providers performing ACDF should consider screening protocols and early referral to providers offering interventions for dysphagia diagnosis and treatment.

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Introduction

The anterior approach to the cervical spine is commonly utilized for a variety of degenerative, traumatic, neoplastic, and infectious indications [1]. Anterior cervical discectomy and fusion (ACDF) is the most frequently performed surgery for degenerative cervical disease, with an average estimated annual case volume of 132,000 and 13.3% projected growth in case numbers from 2020 to 2040 [2, 3]. The anterior cervical approach is a technically safe method in which the structures in the anterior and anterolateral neck are dissected and retracted to provide direct access to the cervical vertebral bodies and intervertebral discs, allowing for discectomy, removal of osteophytes, and, when required, corpectomy of cervical vertebrae [4].

In multiple studies, overall morbidity rates for ACDF varied from 13.2 to 19.3% [1, 5]. The most common complications of ACDF surgery in descending order of

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frequency include: dysphagia, postoperative hematoma, hoarseness, exacerbation of myelopathy, wound infection, esophageal perforation, and instrument failure [1, 5]. Dysphagia remains the most commonly reported complication of ACDF based on administrative coding data, yet its incidence varies widely in the literature, with recent systematic reviews suggesting a range of 1–79% and 0.2–87.5% [1, 6, 7].

The precise pathophysiology of post-ACDF dysphagia is not clearly understood. Contributing factors to swallowing dysfunction include prevertebral soft tissue edema, hematoma, bleeding, neuropraxia from nerve compression or retraction, inflammation associated with anterior cervical hardware irritation, esophageal retraction, or intubation injuries [5, 7, 8]. Currently, there is no consensus protocol or guidelines for assessing post-ACDF dysphagia. Moreover, a review of the existing literature revealed that most studies are small in sample size and retrospective in nature with inconsistent use of validated patient-reported outcome tools or instrumental swallowing evaluations [7, 9]. A recent scoping review showed that nearly half of the ACDF dysphagia literature relies on unvalidated patient-reported outcome measures [9]. Ideally, dysphagia symptoms should be identified with objective screening tools and patient-reported outcome measures that are psychometrically valid. Swallowing dysfunction should be further assessed using gold standard instrumental assessments of swallowing, such as the modified barium swallow study (MBSS) and fiberoptic endoscopic evaluation of swallowing (FEES). Furthermore, no consensus guidelines exist in the current literature regarding a standardized approach to the screening, evaluation, or treatment of dysphagia or swallow dysfunction post-ACDF.

Dysphagia is a heterogeneous construct that encompasses a spectrum of symptoms and physiologic impairments. Importantly, diagnosis codes for dysphagia in administrative datasets typically reflect patient-reported symptoms rather than objective evidence of swallowing dysfunction confirmed via instrumental evaluation (e.g., MBSS or FEES). Prior work has shown that dysphagia symptoms and confirmed physiologic impairment often misalign, particularly in populations undergoing cervical spine surgery or with neurologic conditions [10]. This distinction is essential for interpreting the prevalence and impact of dysphagia following ACDF, and highlights the need for greater diagnostic precision in both clinical and research settings.

In the context of the current literature limitations and high ACDF surgical volume with significant anticipated future growth, the goal of the current study is to utilize a large database of United States healthcare insurance claims to investigate the incidence of dysphagia post-ACDF as well as risk factors for dysphagia and interventions performed in a large patient cohort.

Methods

Database and Data Collection

This retrospective cohort study was conducted using data from the PearlDiver Patient Records Database (Colorado Springs, CO; www.pearldiverinc.com). The dataset contains de-identified insurance claims information from over 151 million patients in the United States from 2010 to 2022. Institutional review board approval was not necessary as the data was de-identified. This information was sourced from all payer types, including commercial insurance, Medicare, Medicaid, and self-pay. International Classification of Disease version 9 and 10 (ICD-9 and ICD-10), and Current Procedural Terminology (CPT) codes were used to retrieve patient records.

A comprehensive list of the codes used is provided as Supplemental Table S1 and S2. Inclusion criteria were adult patients (≥18 years old) undergoing primary ACDF between the years 2010–2022 without a preexisting diagnosis of dysphagia by ICD-9 and ICD-10 coding. Patients undergoing revision ACDF or with preexisting dysphagia diagnosis were excluded. Patients meeting inclusion criteria were divided into two cohorts consisting of those with a new postoperative ACDF diagnosis of dysphagia and those with no ICD-9 or ICD-10 code of dysphagia following primary ACDF. Timing of new dysphagia ICD code was assessed and categorized into three groups: 0–6 months, 6–12 months, and more than 12 months following ACDF surgery. Demographic data of interest, including age, gender, comorbidities (smoking, Diabetes Mellitus, obesity), and prior neck surgery (thyroid surgery, carotid endarterectomy), was collected for every patient meeting inclusion criteria. Intraoperative and postoperative outcomes tested included Multi-level ACDF, adjacent segment disease, pseudoarthrodesis, and vocal fold paralysis. Dysphagia related interventions were also compared between post ACDF dysphagia and non-dysphagia groups and included pre and post laryngoscopy, post ACDF modified barium swallow study (MBSS) and fiberoptic endoscopic evaluation of swallowing (FEES).

Statistical Analysis

Statistical analyses were performed to evaluate the incidence of postoperative dysphagia and the prevalence of associated diagnostic and therapeutic interventions. Incidence was defined as the first occurrence of a dysphagia

Table 1 Demographics of all patients undergoing primary ACDF

Demographics	*n* (%)
Age distribution in years	
≤19	1124 (0.2)
20–49	183,607 (30.6)
50–64	273,090 (45.5)
65–79	138,997 (23.1)
≥80	3958 (0.7)
Gender	
Female	320,573 (53.4)
Male	280,206 (46.6)
Comorbidities	
Smoking	188,357 (31.4)
Diabetes Mellitus	175,334 (29.1)
Obesity	134,672 (22.4)
Surgical History	
History of thyroid surgery	2489 (0.4)
History of carotid endarterectomy	950 (0.2)

diagnosis ICD code postoperatively, while prevalence was calculated for procedures and services such as instrumental swallow evaluations, vocal fold assessments, and therapy encounters.

Univariate analyses were conducted to identify associations between patient- and surgery-level characteristics and the development of postoperative dysphagia, as defined. Odds ratios (ORs) and 95% confidence intervals were calculated for each predictor. A conservative threshold of $p<0$ 0.01 was used to minimize the risk of Type I error given the large sample size. Multivariate modeling was not performed due to the limitations of coding-based administrative data and the primary aim of generating unadjusted, hypothesis-generating associations rather than establishing independent predictors. Statistical analyses were conducted using R version 4.2.1. integrated within PearlDiver, with the following packages: dplyr, stats, ggplot2, as well as with Microsoft™ Excel version 16.94.

Results

Between 2010 and 2022, 618,170 patients undergoing ACDF surgery were identified. Of these, complete data were not available for 17,391, and thus 600,779 were included for final analysis (Table 1). Overall, 88,899 (14.8%) patients were found with a new post ACDF ICD code for dysphagia. Among the 88,899 patients with a new dysphagia code, 82,164 had data regarding timing of diagnosis available. Out of these patients with available timing data, 15,411 (18.8%) patients were diagnosed with dysphagia in first 6 months following ACDF surgery, 5,178 (6.3%) patients between 6 and 12 months following ACDF surgery, and 61,575 (74.9%) patients were first diagnosed with dysphagia more than 12 months following ACDF surgery (Fig. 1).

Demographic data is detailed in Table 1. Patients aged 50–64 at time of surgery represented the largest age group at 45.5% of the overall cohort, followed by 20–49 years (30.6%). Over half (53.4%) of patients were female. The comorbidity identified with the highest frequency was smoking, representing 31.4% of the cohort, followed by diabetes mellitus at 29.1%.

Patients aged more than 65 years at time of surgery were associated had higher odds of being assigned a new ICD dysphagia code after ACDF, while patients aged less than 50 years were found with lower odds of having a new dysphagia diagnosis coded ($p<0.0001$) (Table 2). Smoking (OR 2.51, 95% CI 2.47–2.54), obesity (OR 2.50, 95% CI 2.46–2.54) and diabetes mellitus (OR 2.18, 95% CI 2.15–2.21) all were associated with higher odds of postoperative ICD code for dysphagia. The same was true for patients with a history of neck surgery such as thyroid surgery and carotid endarterectomy. These patients were associated with higher odds of dysphagia diagnosis code (OR 2.94, 95% CI 2.71–3.20; OR 3.31, 95% CI 2.90–3.78 respectively).

Table 3 represents procedure related CPT and ICD-9/ICD-10 codes of interests with associated ORs of dysphagia

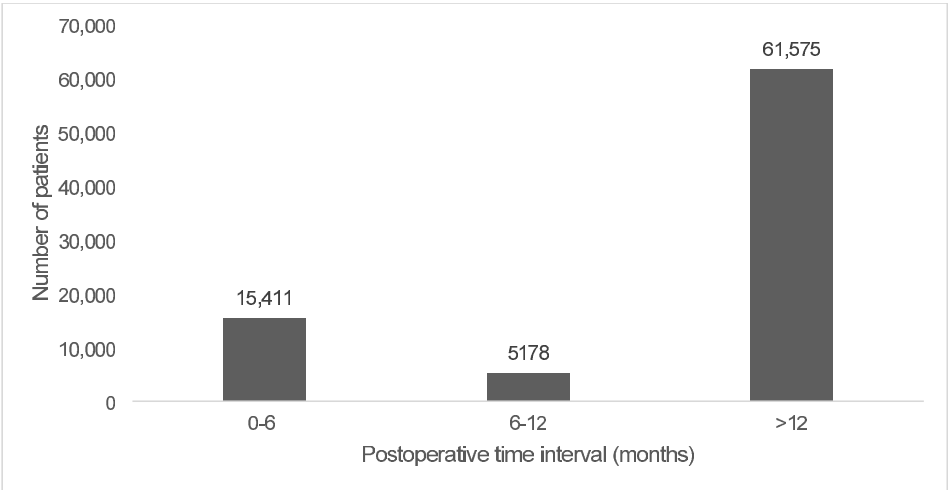

Fig. 1 Timing of new dysphagia diagnosis post ACDF

Table 2 Demographic data stratified by cohort with associated odds ratios for dysphagia diagnosis

	Dysphagia ($n=88899$)	No dysphagia ($n=511880$)	OR [95% CI[a]]
	n (%)	n (%)	
Age Distribution in years			
≤19	126 (0.1)	998 (0.2)	0.73 [0.73, 0.87]*
20–49	20,020 (22.5)	163,587 (31.9)	0.62 [0.61, 0.63]*
50–64	40,558 (45.6)	232,532 (45.4)	1.01 [0.99, 1.02]
65–79	27,113 (30.5)	111,865 (21.9)	1.57 [1.54, 1.59]*
≥80	1073 (1.2)	2885 (0.6)	2.16 [2.01, 2.31]*
Gender			
Female	49,819 (56.0)	270,754 (52.9)	1.14 [1.12, 1.15]*
Male	39,080 (44.0)	241,126 (47.1)	0.88 [0.87, 0.89]*
Comorbidities			
Smoking	44,079 (49.6)	144,278 (28.2)	2.51 [2.47, 2.54]*
Diabetes Mellitus	39,220 (44.1)	136,114 (26.6)	2.18 [2.15, 2.21]*
Obesity	33,815 (38.0)	100,857 (19.7)	2.50 [2.46, 2.54]*
Surgical History			
History of thyroid surgery	838 (0.9)	1651 (0.3)	2.94 [2.71, 3.20]*
History of carotid endarterectomy	346 (0.3)	604 (0.1)	3.31 [2.90, 3.78]*

*$p<0.0001$

[a]CI, confidence interval

Table 3 Procedure related variables of interest with associated ORs for dysphagia

	Dysphagia ($n=88899$)	No dysphagia ($n=511880$)	OR [95% CI[a]]
	n (%)	n (%)	
Multi-level ACDF[a]	34,409 (38.7)	184,468 (36.0)	1.12 [1.10, 1.14]*
Post ACDF[a]pseudoarthrodesis	3586 (4.0)	12,111 (2.4)	1.73 [1.67. 1.81]*
Post-op adjacent segment disease	2426 (2.7)	11,051 (2.2)	1.27 [1.22, 1.33]*
Post ACDF[a]vocal fold paralysis	2372 (2.7)	1610 (0.3)	8.69 [8.15. 9.26]*

*$p<0.0001$

[a]ACDF, Anterior cervical discectomy and fusion

Table 4 Pre and post-operative interventions of interest and associated ORs

	Dysphagia ($n=88899$)	No dysphagia ($n=511880$)	Total ($n=600779$)	OR [95% CI]
	n (%)	n (%)	n (%)	
Pre ACDF surgery laryngoscopy	9326 (10.5)	15,610 (3.1)	24,936 (4.0)	3.73 [3.63, 3.83]*
MBSS[a]	16,879 (19.0)	7120 (1.4)	23,999 (3.9)	16.61 [16.14, 17.10]*
FEES[b]	710 (0.80)	194 (0.04)	904 (0.1)	21.23 [18.11, 24.89]*
Post ACDF surgery laryngoscopy	13,186 (14.8)	16,340 (3.2)	29,526 (4.8)	5.28 [5.16, 5.41]*
Swallow therapy	4639 (5.2)	1682 (0.3)	6321 (1.0)	16.70 [15.79, 17.67]*

*$p<0.0001$

[a]MBSS, Modified barium swallow study; [b]FEES: Fiberoptic endoscopic evaluation of swallow

diagnosis code post ACDF. About one-third of the total cohort (36.4%) underwent multiple-level ACDF, defined as a fusion of two or more spinal levels. Multiple level ACDF was associated with higher odds of receiving a dysphagia diagnosis code (OR 1.12, 95% CI 1.10–1.14,). Diagnosis of post ACDF pseudoarthrodesis or adjacent segment disease was also associated with increased odds of receiving a dysphagia diagnosis code (OR 1.73 [95% CI 1.7–1.81], and 1.27 [95% CI 1.22–1.33] respectively). The rate of postoperative vocal fold paralysis in patients assigned a new ICD code for dysphagia diagnosis post ACDF was 2.7% compared to 0.3% of patients without a new dysphagia diagnosis code (OR 8.69, 95% CI 8.15–9.26).

Table 4 presents pre and post op ACDF swallow-related diagnostic and therapeutic interventions. Patients with new code for dysphagia diagnosis post ACDF were significantly more likely to receive postoperative laryngoscopy, compared to patients without a new code for dysphagia diagnosis post ACDF (OR 5.28, 95% CI 5.16–5.41, $p<0.0001$). Post ACDF dysphagic patients were also more likely to receive pre-op laryngoscopy (OR 3.63, 95% CI 3.53–3.83, $p<0.0001$). Approximately one-fifth (19.8%) of patients with new diagnosis code post ACDF underwent instrumental swallow assessment, largely MBSS (19.0%), with 0.80% undergoing FEES. Only 4,369 (5.2%) of patients that were assigned a new post ACDF dysphagia diagnosis code received swallow therapy.

Discussion

Postoperative dysphagia following ACDF surgery is a serious complication that is associated with increased readmission rate, morbidity, and mortality [11, 12]. This current large-scale cohort database analysis adds to the literature on dysphagia following ACDF surgery. Alsoof et al. performed a similar analysis utilizing the same PearlDiver database; however, their analysis was focused on comparing post-ACDF dysphagia of patients with and without a history of thyroidectomy [13].

Based on our results, 88,899 patients out of 600,779 undergoing primary ACDF were assigned a new ICD code of dysphagia postoperatively, representing 14.8% of the total cohort. This is in line with previous systematic reviews that showed a mean incidence of 8.5–19.4%, depending on inclusion criteria [6, 7]. The timing of dysphagia incidence was notably variable, as the majority of our cohort first received a code for dysphagia diagnosis more than 12 months post ACDF surgery (18.8% first 6 months, 6.3% between 6 and 12 months, and 74.9% over 12 months following from ACDF surgery). Our finding on timing of postoperative dysphagia diagnosis coding contrasts with many other studies that suggest that most cases of postoperative ACDF dysphagia are limited to the immediate and short-term period after surgery and resolve within 1 year [1, 14, 15]. Many of the conclusions of these studies are directly limited by the short-term follow-up interval or the lack of a specified follow-up period. One study reporting on long-term follow-up after ACDF surgery found that as many as 35.1% of patients continued to report persistent dysphagia on a subjective severity scale at an average follow up time of 7.2 years [16]. There is no clear explanation as to why more patients will be diagnosed with dysphagia later, and this phenomenon is under-investigated and underreported in the spine literature. This observation may reflect under-screening in the immediate postoperative period, inconsistent follow-up practices, and variability in symptom recognition by treating providers. Prior work by Haller et al. and Kaufman et al. has underscored these limitations, highlighting that spine teams often under-code or under-recognize swallowing dysfunction [17, 18]. Additional barriers to early detection include a lack of standardized dysphagia screening protocols, limited perioperative counseling, and patient reliance on symptom self-reporting before seeking evaluation. Moreover, this delay can also be secondary to surgical site changes over time such as fibrosis, graft migration with downstream impact on swallow function. The findings should be interpreted within the context of the data source. The identification of dysphagia in this study was based on diagnosis codes derived from clinical encounters, which may reflect subjective symptom reporting rather than confirmed swallowing dysfunction. This distinction is critical, as prior research has shown that symptom-based reports do not always correlate with physiologic swallowing abnormalities [10]. Therefore, the rates presented here likely represent diagnosed symptomatic dysphagia and may under- or overestimate the actual burden of physiologic impairment.

Establishing risk factors for dysphagia is important for surgeons to consider when counseling patients on surgical expectations. Based on our results, and in accordance with the literature, the following were found as risk factors associated with the development of post-ACDF dysphagia: female gender, obesity, older age, smoking, multilevel surgery, and history of neck surgery [7, 18–21]. There is no conclusive evidence as to the mechanism by which certain identifiable risk factors associated with higher likelihood of developing dysphagia postoperatively. We hypothesize that operating in a previously operated field (i.e. patients with prior neck surgery) and surgical approaches that require a wider field of dissection (i.e. multi-level surgery) carries a higher risk of iatrogenic injury to critical structures such as the RLN, esophagus and leads to longer retraction times and increased postoperative edema. Indeed, prior neck surgery as well as multi-level surgery has been found to be significantly associated with increased risk of post ACDF dysphagia [13, 22]. Alsoof et al. utilized the same PearlDiver database to analyze rates of dysphagia in patients with prior thyroidectomy, finding that patients with prior thyroidectomy had significantly higher risk of dysphagia at 1 year than those without prior thyroidectomy (aOR 1.39, $p<0.004$) [13]. Additionally, risk factors associated with poor wound healing such as smoking and diabetes mellitus were also associated with increased odds of dysphagia in our study (OR 2.51, 2.18, $p<0.0001$ respectively). A recent systematic review and meta analysis by Zheng et al.l supports the association between smoking and post ACDF dysphagia, finding a pooled OR of 1.49 (95% CI 1.09–2.10) for development of dysphagia post ACDF in smokers [23]. The authors proposed several mechanisms whereby cigarette smoke may negatively impact postoperative healing leading to downstream tissue degeneration within the operated field, which may negatively impact swallow function leading to dysphagia symptoms [23]. A critical challenge in interpreting both our findings and those of prior studies is the inconsistency in how the term “dysphagia” is defined and captured. Molfenter et al. showed that nearly half of the ACDF dysphagia literature relies on unvalidated patient-reported outcome measures [9]. Some referenced studies relied on patient-reported outcomes gathered via clinical interview or questionnaires, others extracted diagnosis codes from administrative claims, and a few incorporated objective measures such as VFSS or FEES. This heterogeneity in outcome measurement impacts the comparability of

prevalence estimates and introduces challenges in synthesizing findings across studies. In the present study, we found the rate of vocal fold paralysis in the cohort of patients with new postoperative dysphagia code to be 2.7% compared to 0.3% of those without dysphagia. A systematic review of the literature from 2020 by Yee et al. showed that the pooled incidence of recurrent laryngeal nerve (RLN) palsy across retrospective studies is 1.2% and across prospective studies is 2.2% [1]. However, it should be noted that in the review study by Yee, RLN palsy was defined as hoarseness, dysphonia, or vocal fold paralysis confirmed endoscopically, whereas the present study only looked at the coded diagnosis of vocal fold paralysis [1]. Another study by Fountas et al. retrospectively analyzed 1015 consecutive patients undergoing first time single-level ACDF, finding a symptomatic RLN palsy rate of 3.1% [24]. In contrast to Yee, Fountas et al. based classification of RLN palsy primarily on clinical symptoms such as hoarseness without consistent endoscopic confirmation [24]. This variability in diagnostic rigor likely contributed to differing reported rates of dysphagia and vocal fold motion impairment and underscores the need for standardized post-ACDF evaluation protocols. Notably, Fountas et al. reported clinical resolution of RLN palsy symptoms within a 12 week period, although only 59.3% of patients with symptomatic RLN palsy had follow up with an Otolaryngology specialist and 9.4% of patients with symptomatic RLN palsy were found to have persistent unilateral palsy despite symptom resolution, within a mean study follow up time of 26.4 months [24].

This is the first study of this scale to specifically evaluate rates of diagnostic and therapeutic swallow-related interventions in the population of patients with dysphagia following ACDF surgery. Our results show that only 14.8% of patients assigned a new dysphagia diagnosis code after ACDF surgery underwent post-operative laryngoscopy, which is usually performed by an Otolaryngologist as part of a routine oropharyngeal assessment. Only one-fifth of patients assigned a new dysphagia diagnosis code after ACDF surgery underwent objective gold standard instrumental oropharyngeal swallow assessment, predominantly MBSS (19.0%) and FEES (0.80%). Moreover, to our surprise, only 5.2% of patients with a new dysphagia diagnosis code after ACDF received swallow therapy, a routine first-line intervention that may be offered to patients with swallow dysfunction. This emphasizes the lack of awareness regarding the diagnosis and treatment of post-ACDF surgery dysphagia. The low rates of instrumental swallow testing and swallow therapy in our cohort raise concerns about potential under-referral for dysphagia management. This care gap has real-world clinical implications. Missed or delayed identification of dysphagia can lead to malnutrition, aspiration-related complications, delayed wound healing, hospital readmissions, and deterioration in quality of life. Financial toxicity, caregiver burden, and preventable healthcare utilization may also result. Starmer et al. emphasized the importance of routine, multidisciplinary dysphagia screening in similar surgical populations — a recommendation that remains highly relevant in this context [25]. Indeed, two recent studies identified rates of subspecialist referral and dysphagia testing in the post ACDF dysphagia population [17, 18]. The study by Haller et al. from 2022 reported that just 14% of patients with persistent dysphagia symptoms 3 months post ACDF were referred for either dysphagia testing or Otolaryngology referral [17]. In that study, 38% of patients had persistent dysphagia symptoms at 3 months postoperatively. Another study by Kaufman et al. found a rate of dysphagia diagnosis of 20.6% within 1 year post ACDF [18]. Of those patients diagnosed with dysphagia, only 66% were evaluated by a dysphagia subspecialist, defined by the study authors as an SLP, Otolaryngologist, or Gastroenterologist. Just 22% of these subspecialist referrals came from the primary surgical team, i.e. spine surgeon, with the remaining referrals identified as originating from self-referral and primary care physician [18]. Indeed, our findings support the prior limited literature that patients with dysphagia after ACDF are not being adequately referred or objectively assessed for their reported symptoms. Patients may benefit from more extensive pre- and post-operative screening, evaluation, and referral to appropriate providers capable of diagnosing and treating dysphagia symptoms following ACDF. We advocate for future studies exploring implementation of standardized perioperative screening tools, such as symptom checklists or routine laryngoscopy, to improve timely detection and referral.

As with all retrospective database studies, there are limitations that should be considered in the interpretation of these results. Several important limitations are inherent to the use of administrative claims data. First, the identification of dysphagia relied on diagnosis codes, which are subject to variability in coding practices and clinical documentation. Not all patients with symptoms may receive a corresponding diagnosis code, and conversely, some codes may be assigned without confirmatory evaluation. Second, the absence of standardized screening protocols following ACDF likely contributes to underreporting. Dysphagia is often identified only when patients initiate complaints, leading to delays in recognition, documentation, and referral. As our findings show, a substantial proportion of diagnoses occur more than one year after surgery, which may reflect delayed onset, delayed access, or delayed documentation of preexisting symptoms. Third, access to swallowing specialty services varies across settings. Limited availability of speech-language pathologists trained in dysphagia evaluation, lack of awareness among surgical teams, and the

absence of referral triggers may all reduce rates of appropriate testing or therapy. Lastly, the dataset lacks clinical details needed to confirm impairment or assess severity, such as findings from instrumental exams or validated patient-reported outcome measures (PROs). Future work should aim to integrate administrative data with electronic health records that include clinical evaluations, PROs, and objective instrumental assessments (e.g., VFSS, FEES) to improve diagnostic accuracy and enable better risk stratification and quality assessment. Efforts were made to capture the true rates of variables of interest in the data set by utilizing a wide range of ICD and CPT codes to capture as many true data points as possible. The PearlDiver database does not include details related to physical examination, imaging, surgical technique, perioperative steroid use, which are all factors previously shown to be associated with ACDF outcomes. While univariate analyses in our study identified several important risk factors, we did not perform multivariate modeling. This decision was based on the inherent limitations of claims data, including the inability to control for surgical variables such as approach, hardware, operative time, or intraoperative events. Our primary aim was hypothesis generation through unadjusted comparisons, laying the groundwork for future, clinically enriched prospective studies. Dysphagia is a broad symptom and diagnosis and is associated with many other medical conditions and surgical interventions, many of which are associated with the same comorbidities identified at high rates in this population.

The main strengths of our analysis are in its size and the addition of an assessment of the rate of interventions for dysphagia diagnosis and treatment in this population.

Conclusions

In this large national cohort study, we found that patients undergoing primary ACDF have higher odds of receiving a new ICD dysphagia diagnosis code after ACDF. A large proportion of patients received this diagnosis code more than one year after surgery, contrasting with previously published literature. The proportion of patients with a diagnosis code for dysphagia following ACDF likely underrepresents the true incidence due to variability in clinical documentation, lack of standardized screening, and under-recognition by providers. Certain patient and procedure-specific risk factors, such as advanced age, smoking, obesity, diabetes, female gender, and multiple level surgery are associated with increased odds of dysphagia diagnosis; due to the univariate nature of our analysis, these findings should be interpreted as exploratory and not causal. Vocal fold motion impairment was diagnosed in 2.7% of patients who received an ICD code for dysphagia. Only a small subset of patients with post ACDF dysphagia are being evaluated or treated for their dysphagia symptoms. These findings suggesting a care-provision gap in this population, underscoring the need for systematic postoperative dysphagia screening and timely referral for instrumental evaluation and management.

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Author Contributions **James Cochran**: Authored manuscript, data analysis, statistics, literature review. **Nancy Deng**: Data collection and analysis, statistics, literature review. **Ameer Tabbaa**: Helped with data gathering, querying the database, and data analysis. **Afshin Razi**: Helped with data gathering, querying the database, and data analysis. **Sara Abu-Ghanem**: Oversaw data collection, contributed to data analysis, and provided revisions to the manuscript.

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Data Availability The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request. Data is located in controlled access data storage managed by Maimonides Health.

Declarations

Conflict of interest The authors of this study have no conflicts of interest to declare.

Ethical Approval All patient information in the database utilized is de-identified and no patient-specific identifiable information was utilized in the analysis.

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