



## Exclusion criteria for dysphagia for outpatient single-level anterior cervical discectomy and fusion using inpatient data from a spine registry

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### ABSTRACT

**Objectives:** Reported incidence of dysphagia after ACDFs has been as high as 79%. There, however, have been no studies that have specifically looked at developing a criteria for reducing the incidence of dysphagia for outpatient ACDFs. The aim of this study was to determine the risks factors for significant dysphagia that will exclude patients from outpatient single-level anterior cervical discectomy and fusions (ACDFs).

**Patients and methods:** Using the Kaiser Permanente Spine registry database, between January 2009 and September 2013, we identified all inpatients (there were no outpatients) who underwent primary elective one-level ACDFs. A cohort of patients were identified with in-hospital length of stay (LOS)  $\geq$  48 h in which the reason for continued admission was primarily significant dysphagia (DG). Patient's demographics and intraoperative data (ACDF levels (upper [C2-3, C3-4], middle [C4-5, C5-6], lower [C6-7, C7-T1]), and operative times (< 100, 100–199,  $\geq$  200, minutes)) was used to determine risk factors for dysphagia.

**Results:** We found 747 single-level ACDF cases with a cohort of 239 (32.0%) who met the criteria for dysphagia (DG) with  $\geq$  48 h admission. The DG group and non-dysphagia group (NDG) had similar demographics. Diabetes was excluded from regression analysis due to the low frequency. Compared to the lower spine level (C5-6, C7-T1), the upper spine level (C2-3, C3-4) ACDF had a higher likelihood for dysphagia (OR = 2.23, 95% CI = 1.35–3.68,  $p = 0.0016$ ); no difference was found for middle spine level (C4-5, C5-6) ACDF.

**Conclusion:** Single-level ACDF at the upper cervical spine (C2-3, C3-4) was found to be the only risk factor for dysphagia with LOS  $\geq$  48 h based on inpatient data from a spine registry. Age, BMI category, gender, ASA classification, smoking, and operative time were not predictive factors. These findings should be used for excluding patients who undergo outpatient single-level ACDF surgery to reduce significant postoperative dysphagia.

### 1. Introduction

Anterior cervical discectomy and fusion (ACDF) is a common procedure often used in the treatment of degenerative disc disease and trauma. Outcomes with relief of pre-operative symptoms have been good, [1–3] but a number of complications are associated with this procedure including, vocal cord palsy, dural tears, vascular injuries, esophageal injuries, recurrent laryngeal nerve palsies, post-operative hematomas, and dysphagia [4,5]. Dysphagia is by far the most reported of these complications; so common that some authors believe it is not a complication, but rather an inevitable side effect of the procedure [4,6,7]. The reported incidence of dysphagia varies from 1 to 79%

[5,8–14]. For outpatient ACDFs it ranges from 0.3%–10%, but most of these studies did not have specific criteria for reducing dysphagia, but rather had exclusion criteria for preventing other complications, such as airway compromise or post-operative hematomas that may also reduce the incidence of dysphagia [15–20].

The high incidence and variability of dysphagia poses a problem in patient selection for outpatient single-level ACDFs. There have been no studies that have specifically looked at the risk factors for dysphagia for these patients. Since most dysphagia does not require hospitalization, our study was focused on studying dysphagia among inpatients who had ACDFs that required continued hospitalization. Using data from an integrated healthcare system between 2009 and 2013 (before

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outpatient ACDF was introduced at our centers), we identified patients who have had primary single-level ACDFs and who had significant dysphagia that kept them in the hospital  $\geq$  48 h. The incidence of dysphagia and its associated risk factors was determined in this cohort.

## 2. Patients and methods

In 2009, Kaiser Permanente (KP), a large integrated US healthcare system, developed a Spine Registry to collect data on instrumented spinal fusions. The registry tracks procedures that utilize spinal implants, including anterior cervical plates, interbody devices, pedicle and lateral mass screws, total disc replacement devices and bone morphogenetic protein (BMP). The data collection and validation process has been previously described [21,22]. Using the KP Spine registry database, between January 2009 and September 2013, we identified all patients who underwent primary elective one-level ACDFs. Excluded from this database were stand-alone cages and artificial cervical disc replacements. Interbodies used were allograft and autografts, although we estimate the majority of the grafts used were allografts based on historical clinical practices at KP where the majority of surgeons use allografts with anterior cervical plates.

During this study period, all these patients were inpatients (admitted for a minimum of 24 h). A cohort of patients were selected with in-hospital length of stay (LOS)  $\geq$  48 h in which the reason for continued admission was primarily significant dysphagia. Dysphagia (DG) was determined from chart review with management that included modification of diet or nasogastric tube placement or percutaneous endoscopic gastrostomy. Exclusion criteria included: LOS less than 48 h, presence of trauma, prior cervical spine surgery, and death within the 30-day follow-up. Risk factors examined included age, gender, body mass index (BMI < 30, 30–34,  $\geq$  35 kg/m<sup>2</sup>), American Society of Anesthesiologists (ASA) classification, smoking history, history of diabetes, ACDF level (upper [C2-3, C3-4], middle [C4-5, C5-6], lower [C6-7, C7-T1]), and operative time (< 100, 100–199,  $\geq$  200, minutes).

The primary outcome assessed was the occurrence of postoperative dysphagia requiring LOS  $\geq$  48 h. This was determined from chart review. Characteristics and management of dysphagia, including modification of diet, original/final diet, NGT/PEG (nasogastric intubation/percutaneous endoscopic gastrostomy) tube placement, persistence of dysphagia, and duration of dysphagia (if resolved) were also collected.

### 2.1. Statistical analysis

Means, standard deviations (SD), medians, interquartile ranges (IQR), frequencies, and proportions were used to describe the study cohort. Conditional logistic regression models were used to evaluate the association between demographic and operative risk factors and post-operative dysphagia; odds ratios (OR), 95% confidence intervals (CI), and Wald Chi-square test p-values were reported. Missing data was excluded (BMI: n = 1, 0.1%; ASA: n = 16, 2.1%; smoking: n = 4, 0.5%; diabetes: n = 47, 6.3%; and operative time: n = 4, 0.5%). Data were analyzed using SAS (version 9.4, SAS Institute, Cary, North Carolina, USA), and an alpha = 0.05 was used as the threshold for statistical significance.

## 3. Results

We identified 747 one-level ACDF cases between January 1, 2009 and September 30, 2013 with length of stay  $\geq$  48 h meeting our study criteria (Fig. 1). Of these 747 patients, 239 (32.0%) met the criteria for dysphagia. For the dysphagia group (Table 1), the mean age was 56.8 years (SD = 12.9) and the majority were female (55.7%), with a BMI < 30 (62.3%), ASA of 1–2 (64.7%), never smokers (45.4%), non-diabetic (90.0%), had an ACDF at the middle level (54.0%), and an operative time of 100–199 minutes (49.2%). Similarly, the non-dysphagia group had a mean age of 55.1 years (SD = 11.9) and the majority were

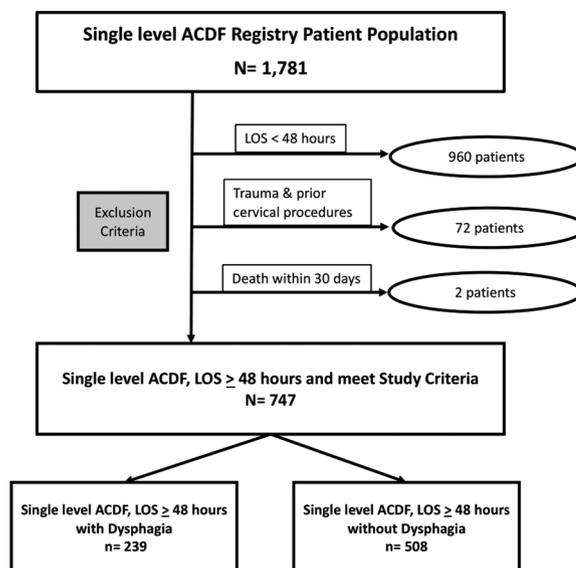


Fig. 1. Summary of patient selection for cohort of one-level ACDF patients with LOS  $\geq$  48 h.

Table 1 Demographics and operative characteristics of one-level ACDF patients stratified by postoperative dysphagia status.

Risk Factor	Dysphagia n (%)	No Dysphagia n (%)
Total cases	239	508
Age		
Mean (SD)	56.8 (12.9)	55.1 (11.9)
Median (IQR)	55.3 (47.2-65.5)	54.3 (47.3-62.9)
Range	26.7-88.5	17.4-95.0
Gender		
Female	133 (55.7)	284 (55.9)
Male	106 (44.3)	224 (44.1)
BMI category		
< 30	149 (62.3)	306 (60.4)
30-34	49 (20.5)	117 (23.1)
$\geq$ 35	41 (17.2)	84 (16.6)
ASA classification		
1-2	152 (64.7)	343 (69.2)
$\geq$ 3	83 (35.3)	153 (30.9)
Smoking		
Never	108 (45.4)	238 (47.2)
Yes/passive	26 (10.9)	78 (15.5)
Quit	104 (43.7)	188 (37.3)
Diabetes		
No	197 (90.0)	481 (100.0)
Yes	22 (10.0)	0 (0.0)
Spine level		
Lower (C6-7, C7-T1)	49 (20.5)	144 (28.4)
Middle (C4-5, C5-6)	129 (54.0)	286 (56.3)
Upper (C2-3, C3-4)	61 (25.5)	78 (15.4)
Operative time		
< 100 minutes	99 (41.6)	202 (40.0)
100-199 minutes	117 (49.2)	256 (50.7)
$\geq$ 200 minutes	22 (9.2)	47 (9.3)

Missing data: BMI: n = 1, 0.1%; ASA: n = 16, 2.1%; smoking: n = 4, 0.5%; diabetes: n = 47, 6.3%; and operative time: n = 4, 0.5%. ASA = American Society of Anesthesiologists, BMI = body mass index, IQR = interquartile range, SD = standard deviation.

female (55.9%), with a BMI < 30 (60.4%), ASA of 1–2 (69.2%), never smokers (47.2%), non-diabetic (100.0%), had an ACDF at the middle level (56.3%), and an operative time of 100–199 minutes (50.7%).

Univariable and multivariable results are presented in Table 2. No associations were found between age, gender, BMI, ASA, smoking history, and operative time and likelihood for dysphagia. Diabetes was

**Table 2**  
Univariable and multivariable conditional logistic models for risk factors<sup>a</sup> of postoperative dysphagia.

Risk Factors	Univariable Models <sup>b</sup>			Multivariable Model <sup>c</sup>		
	OR	95 % CI	p	OR	95 % CI	p
Age, 1-year increments	1.01	(1.00-1.02)	0.087	1.00	(0.98-1.01)	0.860
Gender						
Female	Ref	–	–	Ref	–	–
Male	1.01	(0.74-1.38)	0.947	0.93	(0.67-1.30)	0.682
BMI category			0.733			0.733
< 30	Ref	–	–	Ref	–	–
30-34	0.86	(0.58-1.27)	0.445	0.85	(0.57-1.27)	0.431
≥ 35	1.00	(0.66-1.53)	0.991	0.95	(0.61-1.50)	0.838
ASA classification						
1-2	Ref	–	–	Ref	–	–
≥ 3	1.22	(0.88-1.70)	0.227	1.12	(0.77-1.62)	0.545
Smoking			0.125			0.229
Never	Ref	–	–	Ref	–	–
Yes/passive	0.74	(0.45-1.21)	0.226	0.73	(0.44-1.21)	0.224
Quit	1.22	(0.88-1.70)	0.240	1.15	(0.81-1.62)	0.433
Spine level			0.002*			0.005*
Lower (C6-7, C7-T1)	Ref	–	–	Ref	–	–
Middle (C4-5, C5-6)	1.33	(0.90-1.95)	0.152	1.26	(0.85-1.87)	0.251
Upper (C2-3, C3-4)	2.30	(1.44-3.66)	0.001*	2.23	(1.35-3.68)	0.002*
Operative time			0.915			0.907
< 100 minutes	Ref	–	–	Ref	–	–
100-199 minutes	0.93	(0.67-1.29)	0.674	0.95	(0.68-1.33)	0.754
≥ 200 minutes	0.96	(0.55-1.67)	0.872	0.89	(0.49-1.60)	0.695

ASA = American Society of Anesthesiologists, BMI = body mass index, CI = confidence interval, OR = Odds Ratio, Ref = Reference.

<sup>a</sup> Diabetes status was excluded from analysis due to the low frequency.

<sup>b</sup> Missing data: BMI: n = 1, 0.1%; ASA: n = 16, 2.1%; smoking: n = 4, 0.5%; and operative time: n = 4, 0.5%.

<sup>c</sup> N = 721.

\* Indicates p < 0.05.

excluded from regression analysis due to the low frequency. Compared to the lower spine level (C6-7, C7-T1), the upper spine level (C2-3, C3-4) ACDF had a higher likelihood for dysphagia (OR = 2.23, 95% CI = 1.35–3.68, p = 0.002); no difference (OR = 1.26, 95% CI = 0.85–1.87, p = 0.251) was found between the middle spine level (C4-5, C5-6) ACDF and the lower spine level (C6-7, C7-T1).

A description of the natural history and management of dysphagia is presented in Table 3. Of the patients suffering from dysphagia, most modified their diet (65.3%). Prior to modification, the majority were on a soft diet (34.5%), followed by NPO (23.4%), ground (22.8%), liquid (10.5%), and normal (8.8%). The final diet was predominately normal (94.2%), followed by NPO (2.9%), soft (2.3%), and liquid (0.6%). NGT/PEG tube placement was unnecessary for most patients (89.1%). Persistent dysphagia was uncommon (9.2%). Mean time to dysphagia resolution was 15.8 days (SD = 54.9). The upper spine levels required a longer time for resolution of dysphagia (22.9 days versus 14.5 days for lowest level).

#### 4. Discussion

Dysphagia is very common after ACDFs and it can occur immediately after surgery but can last as long as 12 months post-surgery [14,23,24]. In most cases, it resolves without the need for hospitalization. The challenge in selecting outpatients for ACDFs is to identify patients with less likelihood of having dysphagia that requires hospitalizations. With this in mind, our study found a cohort of single-level ACDF inpatients with ≥ 48 h of hospitalization. The incidence of postoperative dysphagia was 32% and the upper spine level (C2-3, C3-4) was the only risk associated with development of dysphagia.

##### 4.1. Natural history of postoperative dysphagia

The timing and natural history of postoperative dysphagia is variable. Data on immediate dysphagia is quite limited. In their review of 104 patients, Liu et al [25] found the incidence of dysphagia in the first

**Table 3**

Characteristics of one-level ACDF patients with a diagnosis of postoperative dysphagia, overall and stratified by spine level.<sup>a</sup>

Characteristic,	Overall n (%)	Spine Level <sup>b</sup>		
		Lower n (%)	Middle n (%)	Upper n (%)
Total N	239	49	129	61
Diet modified	156 (65.3)	31 (63.2)	87 (67.4)	38 (62.3)
Original diet				
NPO	40 (23.4)	4 (12.5)	26 (27.4)	10 (22.7)
Liquid	18 (10.5)	5 (15.6)	5 (5.3)	8 (18.2)
Soft	59 (34.5)	11 (34.4)	37 (38.9)	11 (25.0)
Ground	39 (22.8)	10 (31.3)	19 (20.0)	10 (22.7)
Normal	15 (8.8)	2 (6.3)	8 (8.4)	5 (11.4)
Final diet				
NPO	5 (2.9)	0 (0.0)	4 (4.2)	1 (2.3)
Liquid	1 (0.6)	1 (3.1)	0 (0.0)	0 (0.0)
Soft	4 (2.3)	0 (0.0)	3 (3.2)	1 (2.3)
Normal	161 (94.2)	31 (96.9)	88 (92.6)	42 (95.5)
NGT/PEG tube placement				
0	213 (89.1)	47 (95.9)	111 (86.0)	55 (90.2)
1	15 (6.3)	0 (0.0)	12 (9.3)	3 (4.9)
2	8 (3.4)	1 (2.0)	5 (3.9)	2 (3.3)
3	2 (0.8)	0 (0.0)	1 (0.8)	1 (1.6)
4	1 (0.4)	1 (2.0)	0 (0.0)	0 (0.0)
Persistent dysphagia	22 (9.2)	5 (10.2)	9 (7.0)	8 (13.1)
Duration of dysphagia if resolved, in days				
Mean (SD)	15.8 (54.9)	14.5 (21.9)	13.2 (32.3)	22.9 (98.4)
Median (IQR)	4 (3-14)	7 (3.5-14)	4 (2-13)	4 (3-8)
Range	0-720	1-120	0-320	1-720

Missing data: Original diet: n = 68, 28.5%; Final diet: n = 68, 28.5%; duration of dysphagia: n = 22, 9.2%.

IQR = interquartile range, NGT = nasogastric tube placement, NPO = nothing by mouth, PEG = percutaneous endoscopic gastrostomy, SD = standard deviation.

\* Spine level: Lower = C6-7, C7-T1; Middle = C4-5, C5-6; and Upper = C2-3, C3-4.

and second day after surgery to be 87.5%, and 79.81%, respectively. Wang et al [26] reported a 20% incidence of immediate dysphagia following mostly single ACDF using a modified Bazaz-Yoo dysphagia questionnaire [23].

Studies on long-term post-operative dysphagia is well documented. Rihn et al [9] found the incidence of dysphagia at two weeks after ACDF was as high as 71%, while Kalb et al [27] found a dysphagia rate of 88.8% six weeks after ACDF. In 2002, Bazaz et al [23] reported a one-month dysphagia rate of 50.2% in their prospective study of 249 patients. This higher incidence maybe due to the inclusion of multilevel ACDF and corpectomies in their study. Yang et al [24] found the incidence of dysphagia in their ACDF group to be 60.43% at one week, 38.85% at one month, 31.65% at three months, 17.99% at six months, and 14.39% at 12 months. Bazaz et al [23] also found after anterior cervical spine surgery dysphagia decreased significantly by 6 months. Shriver et al [28] reported dysphagia rates decreased drastically between follow-up times of less than 12 months (19.9%) and 12–24 months (7.0%), and then stabilized with further follow-up. Both studies, however included multilevel ACDFs, with Yang et al [24] finding that two-level fusions carried a higher risk for dysphagia than single level ACDF.

It should be noted Kang et al [29] found dysphagia did not appear to be a chronic condition for most patients, rather chronicity appears to have a relationship with psychiatric diagnosis. A significant portion of dysphagia-suffering patients modified their diet during the post-operative timeframe with only 10.88% of patients requiring the use of NGT/PEG tube in management. Unlike these studies we found dysphagia was a transient complication for 90.79% patients with a mean resolution time of 15.82 days. The limitation in our study, however, was that we only studied patients admitted for dysphagia  $\geq$  48 h and with only a 30-day follow-up period.

#### 4.2. Demographic risk factors for dysphagia

Previously reported risk factors for dysphagia have been associated with the patients' demographics and intraoperative factors [23,24,29–41]. Bazaz et al [23] found that female patients with age  $\geq$  60 years old were at high risk for dysphagia. Olsson et al [42] found that patients with smoking were more likely to suffer from dysphagia. This was similar to Wang et al [26] and they found smoking and diabetes were the only 2 risk factors, that could slow rehabilitation of dysphagia at 2-year follow-up. In contrast to these studies, we did not find age, BMI category, gender, ASA classification, smoking, or operative time to be risk factors for developing postoperative dysphagia for  $\geq$  48 h of follow-up

#### 4.3. Intraoperative risk factors for dysphagia

Reported intraoperative risk factors for dysphagia include: pre-vertebral soft tissue swelling, [33] significant esophageal retraction, revision surgery [10], number of levels fused, the thickness of the plate [30,38]. and the level of the fusion [5,24,26,27,45,31,32,60–62]. At present, the exact pathophysiological mechanism of dysphagia remains unclear. Fountas et al [5] reported that the occurrence of dysphagia might be related to esophageal injury, thickening and adhesion of prevertebral soft tissue edema, and postoperative hematoma. Liu et al [49] suggested avoiding prolonged operative times, and excessive lordosis of the cervical spine to decrease early and persistent dysphagia. This has led the use of zero-profile devices [24,33,43,44,50,51,60]. such as cervical disc replacement devices or zero-profile implants also called anchoring cages or stand-alone cages. The later consists of a cage and an internal implant with a pair of locking screws. Segebarth et al [33] and McAfee et al [43] found a significantly lower rate of dysphagia with no-profile cervical disc arthroplasty compared to instrumented ACDF for single level disc disease between C3-7. Sun et al [52] performed an exhaustive meta-analysis of 8 studies (3 prospective and 5

retrospective) [53–60], and found that zero-profile implants had significantly reduced incidence of postoperative dysphagia compared with the cage and plate constructs. Their study, however, only reported dysphagia that occurred  $>$  3 months after surgery, leaving very little insight in how this will reduce short-term dysphagia especially for a criteria for outpatient ACDF.

The relationship between the level of surgery and dysphagia has only been reported in a few studies with mixed results [24,26,27,32,45,61,62]. Lee et al, [62] followed 310 patients for 2 years who had single and multilevel ACDFs and found although there was a decrease in the prevalence of dysphagia with single-level surgery at C5-6, it was not statistically significant when compared to surgery at C3-4 and C6-7. Kalb et al [27] had similar results among 249 patients with 27 (10.8%) having post-operative dysphagia within the first 6 months. Patients who developed dysphagia were most often treated at C4-5 (67%) and C5-6 (81%;  $P < 0.001$ ).

More recent studies, however, have shown different results. Kang et al [32] assessed the risk of dysphagia among 17 patients who had artificial disc replacements and 28 ACDFs of which 13 had single level fusions. The study found in the ACDF group with dysphagia, there was an increase in prevertebral soft tissue thickness within 48 h of surgery, but at 1 month, 3 months, and 6 months post-surgery, these differences were not significant. The risk of dysphagia was significantly higher in patients who had their highest operative level at C3 or C4. Similarly, Yang et al [24] in 2016 retrospectively studied 158 patients with anterior cervical discectomy and fusions and 231 patients with cervical disc replacements and noted that surgery at the upper cervical spine (C4-5) was associated with a higher incidence of postoperative dysphagia among the ACDF patients. This study may also implicate that the use of the low-profile cervical disc replacements may also reduce the risk of dysphagia for mid- and long-term follow-up.

In 2017, several larger studies were reported [26,45,61,62]. Wu et al [45] in their review of 358 patients who had single and multi-level ACDFs, early dysphagia (1–5 days) was found in 10.9% of the patients with none reporting severe dysphagia by 3 months. They found multilevel and high-level cervical spine surgeries were the highest risk factors for postoperative dysphagia. Liu et al, [61] in their meta-analysis of papers on risk factors for dysphagia after anterior cervical spine surgery analyzed Wu et al [45] and Lee et al [62] papers and concluded that the upper surgical level at C3/4 was a risk factor for dysphagia following anterior cervical spinal surgery (OR = 3.08, 95% CI: 1.44–6.55,  $P = 0.004$ ). They also noted the results should be cautiously interpreted due to the small numbers for single level fusions. Wang et al, [26] presented a much larger series in a multicenter retrospective study with of 2827 patients who received anterior cervical surgery. The rate of dysphagia after anterior cervical surgery immediately was 20% (566 of 2827). They also found a higher risk of dysphagia with surgery at the C2 to C3 or C6 to C7 levels.

Our findings are similar to the majority of studies presented so far, although most of the studies had significant heterogeneity in the type of anterior cervical spine surgery that was done (multilevel, corpectomies, arthroplasty, zero-profile plates etc.) as well as smaller sample sizes [27,32]. Our study is unique in that it has one of the largest cohort of single-level ACDFs and specifically addresses the presence of early dysphagia ( $\geq$  48 h). We found in single level ACDFs at the upper spine level (C2-3, C3-4) carries 2.30 times higher likelihood of developing postoperative dysphagia compared to surgery at the lower cervical region (C6-7, C7-T1).

The reason for the high incidence of dysphagia at the higher cervical levels is unknown. Some believe risk of damage to superior laryngeal nerve increases, [45] others believe it is an anatomical causation due to larger retropharyngeal space at the upper cervical spine compared to the inferior cervical spine which makes the soft tissue swelling more severe [62].

#### 4.4. Dysphagia after outpatient ACDF

Comparisons of incidence of dysphagia between inpatient and outpatient ACDFs have been reported with varying differences [15–20]. Liu et al [18] studied 64 patients who underwent ACDF as inpatients with 45 as outpatients and found a low risk of moderate dysphagia in the outpatient group (0% versus 1.6%). Stieber et al, [20] on the other hand, reported a higher risk for outpatients (10%) compared to inpatients (5%) in experiencing dysphagia, but none were admitted. Their criteria for outpatient selection was the level for surgery had to be C4-5 or lower, absence of myelopathy, subjective neck size, and low estimated operative time. The outpatient group had a lower overall complication rate compared to inpatients. This was likely the result of selection bias. Transient dysphagia was the most prevalent complication in the outpatient group. Similar results have been found in larger studies as reported by McGirt et al, [19] who found safety in outpatient ambulatory settings for one- to two-level ACDF using data from a national database. Adjusted comparison using multivariable logistic regression demonstrated that ACDF performed in the outpatient setting had 58% lower odds of having a major morbidity and 80% lower odds of return to the OR within 30 days. When their work was extended two years later, they found a surgical complication rate of 1% among 1000 outpatient ACDFs with 620 one-level and 365 two-level ACDFs [15]. Interestingly they found among the one-level cohort of outpatients there was a higher rate of dysphagia requiring alteration in diet compared to the inpatient cohort (1.8% vs 0.0%). Both studies however gave no detailed information on risks factors for dysphagia.

#### 4.5. Limitations of our study

Limitations of our study include its retrospective design and lack of a universal method for evaluating dysphagia. We acknowledge there may have been large heterogeneity among surgeons in recognizing dysphagia without a standardized evaluating tool, but we believe the surgeons had to justify patients having a longer hospital stay for dysphagia with input from other supportive staff members (speech therapy, dieticians etc.) with rigorous guidelines for inpatient length of stay within an integrated healthcare system. The Bazaz Dysphagia Score has been used in several other studies and maybe a useful method to be used in our future studies [23,28,43]. Also, another criticism was that we did not include the group of patients with LOS  $\geq$  24 h and  $<$  48 h. We did this deliberately to have a conservative estimate of our risks of dysphagia because of its high incidence.

We did not study the use of pre-operative steroids for reducing dysphagia. We acknowledge the administration of topical versus intravenous corticosteroids is controversial showing mixed results in the literature [46–48]. In a large cohort of patients like ours with various surgeons the consistency of use of pre-operative steroid was variable. Something we hope to evaluate in future studies. We also did not evaluate more modern instrumentation such as the zero profile, which based on the literature are having very promising results in reducing dysphagia, although its use in the outpatient setting has not been elucidated. We believe we can also address this in future studies.

Our study has the advantage of having the largest cohort of patients from an integrated healthcare system. Most studies (other than from national databases) did not have sufficient sample sizes to make meaningful conclusions on inpatient dysphagia and many of the outpatient studies inherently had selection and confounding biases that limited their usefulness for patient selection. We acknowledge complications like dysphagia are not comparable to complications such as airway compromise, hypoxia, and even death., but we believe that knowledge of risks factors for dysphagia will guide us not only for appropriate outpatient selection but will help guide us in the follow-up care that reduces patient anxiety and readmissions.

## 5. Conclusions

In review of the literature, our paper showed that there was a research gap in selecting outpatients for single-level ACDFs with low risk for significant post-operative dysphagia. Although our findings were similar to criteria used in some previous studies for reducing other complications, it was the first and only study that provided evidence for a selection criteria specifically for reducing significant post-operative dysphagia. We found, using inpatient data for single-level ACDF patients without previous surgery, that the upper cervical spine (C2-3, C3-4) was the only risk factor for dysphagia with LOS  $\geq$  48 h. Age, BMI category, gender, ASA classification, smoking, and operative time were not predictive factors. These findings can be extended to exclude patients for outpatient single-level ACDF surgery in order to reduce significant postoperative dysphagia and readmissions.

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