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Heterogeneous Presentations of Pharyngoesophageal Diverticula Occurring after Cervical Spine Surgery

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Abstract

Dysphagia after anterior cervical spine surgery (ACSS) may be secondary to pharyngoesophageal diverticulum. Our objectives are to (1) highlight the heterogeneity in clinical presentation, (2) discuss pathophysiology and management, and (3) present a comprehensive literature review of these diverticula. All patients undergoing pharyngoesophageal diverticulum repair between 2013 and 2019 were identified. Cases with ACSS history underwent detailed review of clinical presentation, assessment, and management. Literature review and analysis of all reported ACSS-associated pharyngoesophageal diverticula was performed. Two hundred forty-three cases of pharyngoesophageal diverticulum repair were performed during the study period; 13 cases were ACSS-associated. Four types of clinical presentation were identified: (Type A) Spinal hardware present, with videofluoroscopic evidence of exposed hardware; (Type B) Spinal hardware present, without videofluoroscopic evidence of exposed hardware; (Type C) Spinal hardware absent due to prior spinal hardware removal or ACSS performed without hardware; and (Type D) Concurrent esophago-esophageal fistula (EEF) present. All of our cases were evaluated using modified barium swallow study and esophagoscopy and definitively managed with endoscopic diverticulotomy. Literature review identified 21 cases of ACSS-associated pharyngoesophageal diverticulum repair from 18 publications. The majority of cases were identified using barium esophagram ($N = 18$, 86%) and managed with open diverticulectomy ($N = 19$, 90%). There were no reports of EEF. ACSS-associated pharyngoesophageal diverticulum must be evaluated with fluoroscopy and endoscopy, which determine presentation type. Presentation type guides management. Esophageal perforation requires hardware removal and perforation repair with flap placement. Endoscopic diverticulotomy was found essential to definitive management.

Keywords

Dysphagia; Pharyngoesophageal diverticulum; Anterior cervical spine surgery; Spine hardware; Endoscopic diverticulotomy

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Conflict of Interest The authors declare that they have no conflict of interest.

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Introduction

Dysphagia after anterior cervical spine surgery (ACSS) varies in degree and duration [1]. Evaluation of ACSS-associated dysphagia often includes radiographic studies. These studies may reveal a pharyngoesophageal (PE) diverticulum that appears radiographically similar to a Zenker's diverticulum (ZD) [2–4]. Before treating as a ZD, the anatomical and pathophysiological differences of ACSS-associated diverticula and ZD must be considered. ZD is a pulsion-type pseudodiverticulum resulting from chronically impaired relaxation of the cricopharyngeus (CP) muscle during deglutition. High intraluminal pressure is generated and eventually leads to herniation of the mucosal and submucosal layers through Killian's dehiscence [5]. In contrast, ACSS-associated diverticulum is considered a traction-type diverticulum resulting from mucosal adherence to cervical spinal hardware. External traction and shearing stress on all layers of the PE wall produce a true diverticulum adjacent to the spinal hardware [6, 7]. The traction-type diverticulum hypothesis has been supported by several reports of dense fibrosis between the cervical hardware and the posterior PE wall [3, 6, 8, 9].

Heterogeneous presentations of ACSS-associated pharyngoesophageal diverticula result from varied pathophysiology and treatment history. Likewise, the assessment and management of these diverticula vary. We analyze the diverse presentations and management methods and define four presentation types. Additionally, we describe a previously unreported finding, esophago-esophageal fistula (EEF), originating from the diverticulum. Finally, we performed a comprehensive literature review of ACSS-associated diverticula reported to date and similarly categorized these by pathophysiology and presentation type. To our knowledge, this study presents the largest case series of ACSS-associated diverticulum. In this report, we discuss pathophysiology, presentation types, assessment methodology, and management algorithm of ACSS-associated pharyngoesophageal diverticula.

Methods

The University of California, Los Angeles Institutional Review Board approved this study. PE diverticula management were coded as Zenker's diverticulum surgery. Therefore, a database was developed using Current Procedural Terminology charge codes for open and endoscopic Zenker's diverticulectomy (codes 43130 and 43180) performed between January 2013 and December 2019 at this institution. Subjects with ACSS history were included. Patient demographics, clinical presentation, diagnostic methodology, management, and complication data were collected from meticulous chart review. Initial and final radiographic findings and swallowing assessment findings were also detailed.

A comprehensive literature search was conducted using the following keywords: Zenker, diverticulum, Zenker's diverticulum, pharyngoesophageal diverticulum, pharyngeal diverticulum, esophageal diverticulum, diverticulectomy, diverticulotomy, cervical spine surgery, anterior cervical spine surgery, anterior cervical discectomy, and fusion complications. The following databases were searched: PubMed, Cochrane, EMBASE, Web

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of Science, and Google Scholar. There were no language, publication year, or publication status restrictions. Additionally, the bibliography of retrieved papers was reviewed. Reports were screened using predetermined inclusion and exclusion criteria. Inclusion criteria were descriptions of pharyngeal and/or esophageal diverticula occurring after ACSS. Exclusion criteria were incomplete presentation or management history, non-surgical management, or ACSS complications that did not include diverticulum formation.

Results

Of 243 patients who underwent PE diverticulum repair during the study period, 13 had ACSS history. The mean age at presentation for dysphagia evaluation was 64 years (range 46–75). The mean time between ACSS and dysphagia evaluation was six years (range 10 months–31 years). There were slightly more males in our series ($N = 8$, 62%). Further analysis revealed four presentation patterns (Types A–D) detailed through illustrative cases below and Table 1.

Type A. Pharyngoesophageal Diverticulum with Perforation and Exposed Cervical Hardware Apparent on Videofluoroscopic Swallow Study. Barium Contrast Contacts the Cervical Spinal Hardware (Subjects 1–2)

A 69-year-old female (Subject 2) presented with frequent throat clearing and dysphagia to soft food one year after ACSS. The cervical outpouching seen on her modified barium swallow study (MBSS) was interpreted as ZD. Upon our review, barium contrast was noted to contact the anterior surface of the cervical hardware, raising suspicion for esophageal perforation with exposed spinal hardware (Fig. 1a). Office transnasal esophagoscopy (TNE) showed exposed hardware and confirmed this suspicion. She underwent transcervical exploration with hardware removal, repair of a 1.5 cm × 1 cm posterior esophageal defect, superiorly based sternocleidomastoid (SCM) rotation flap reconstruction, and gastrostomy tube (G-tube) placement. Three months later, she underwent transoral CO_2 laser diverticulotomy of a persistent party wall. The G-tube was removed two weeks later, and she resumed a regular diet. Follow-up MBSS showed resolution of the diverticulum (Fig. 1b).

Type B. Pharyngoesophageal Diverticulum Adjacent to Spinal Hardware Without Apparent Contact of Barium with the Cervical Hardware. Esophagoscopy Required to Evaluate if Perforation with Exposed Hardware is Present (Subjects 3–8)

A 54-year-old female (Subject 3) was referred for progressive dysphagia attributed to ZD. She had multiple cervical spine surgeries, most recently C4–C7 fusion performed six months prior to presentation. MBSS showed a 3 × 3 cm diverticulum adjacent to spinal hardware (Fig. 2a), but barium did not contact the cervical hardware plate. Flexible endoscopic evaluation of swallowing demonstrated severe esophagopharyngeal reflux with all food consistencies, concordant with ZD [5]. She was brought to the operating room for endoscopic laser diverticulotomy. However, rigid endoscopy revealed exposed spinal hardware and a large-mouthed perforation (Fig. 2b), and the diverticulotomy was aborted. She subsequently underwent transcervical spinal hardware removal, repair of a 4 cm esophageal perforation, SCM rotation flap reconstruction, and G-tube placement. Three months later, transoral CO_2 laser diverticulotomy was performed, followed by the

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resumption of regular diet and G-tube removal. Interestingly, she was found to have developed an esophago-esophageal fistula (EEF) at the time of endoscopic diverticulotomy (Type D, described below). The EEF was not repaired.

Type C. Pharyngoesophageal Diverticulum After History of Cervical Hardware Removal, or ACSS Without Hardware Placement. Videofluoroscopy Revealed Diverticulum (Subjects 9–13)

A 46-year-old female (Subject 9) presented with dysphagia five years after ACSS. Two years after ACSS, she experienced progressive dysphagia and odynophagia after a motor vehicle accident. Six months later, esophageal perforation with hardware exposure was discovered at an outside hospital. She underwent hardware removal, and the esophageal perforation was allowed to heal secondarily. Follow-up barium esophagram (BE) demonstrated diverticulum and an esophago-esophageal fistula (EEF). She underwent attempted EEF repair, SCM flap reconstruction, and G-tube placement. Additional EEF repair attempts were complicated by Horner's syndrome with ipsilateral ptosis, miosis, and anhydrosis. She then presented at our institution for further evaluation. Office TNE revealed the fistula origin at the base of an apparent diverticulum (Fig. 3a). MBSS demonstrated a pharyngoesophageal diverticulum with an EEF opening at the diverticular base. She underwent transoral CO_2 laser diverticulotomy, during which a Savary guidewire inserted into the EEF opening emerged 4 cm distally into the esophageal lumen. The EEF was not repaired. Postoperatively, her dysphagia resolved, and MBSS showed complete diverticulotomy with persistent EEF (Fig. 3b).

Type D. Pharyngoesophageal Diverticulum Associated with Concurrent Esophago-Esophageal Fistula (Subjects 3, 9, 11)

A 56-year-old female (Subject 11) presented with a history of drainage of a retropharyngeal abscess and hardware removal to treat an esophageal perforation one year after ACSS. Three years later, she developed regurgitation of undigested food and underwent G-tube placement. One year later, she presented to our institution for further evaluation of her dysphagia. Esophagram revealed PE diverticulum and concurrent EEF (Fig. 4a). Intraoperative diverticuloscopy revealed an EEF originating at the diverticular base (Fig. 4b) that drained 3 cm distally into the esophageal lumen. She underwent transoral CO_2 laser diverticulotomy (Fig. 4c) with dysphagia resolution and subsequent G-tube removal. The EEF was not repaired.

Literature Review

Twenty reports of pharyngoesophageal diverticula associated with ACSS were identified (Table 2). Two papers were excluded due to limited descriptions of presentation and prior surgical management [2, 22]. The remaining 18 articles presented a total of 21 cases. The mean age at presentation for dysphagia evaluation was 44 years (range 22–70), and the mean duration between ACSS and dysphagia evaluation was 4.2 years (range 6 months –18 years). Gender distribution was comparable across reports (N = 11, 52% female). Diverticula were most commonly diagnosed using barium esophagram (N = 18, 86%). Open diverticulectomy was the most common approach (N = 19, 90%). Pharyngoesophageal perforation was found intraoperatively in 12 cases (57%). Management often included hardware removal (N = 14,

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67%), either concurrently with diverticulectomy or as part of a staged approach. Flap reconstruction of esophageal perforation was described in 7 cases (33%).

Complications of open diverticulectomy included salivary fistula and unilateral vocal fold paralysis [6, 12]. Only 2 cases described successful endoscopic diverticulotomy that did not require revision, one using Dolhman's endoscopic diathermy and another using the linear stapler [19, 21]. Complications of unsuccessful endoscopic diverticulotomy included recurrent dysphagia at 35 months secondary to newly exposed cervical hardware; this was managed with hardware removal, open repair, and forearm free flap placement [18]. Another reported dehiscence of the proximal stapler line requiring secondary sternocleidomastoid (SCM) flap placement [13].

Discussion

Pathophysiology of Pharyngoesophageal Diverticula and Esophageal Perforation

Chronic spinal hardware contact with the PE wall after ACSS may cause pressure necrosis and eventual PE perforation [23]. Perforation is more likely to occur at Killian's triangle. At Killian's triangle, the hardware is separated from the PE wall by only the buccopharyngeal and prevertebral fascia layers, rendering it an area of relative weakness that is more susceptible to instrumental injuries [24, 25]. In the setting of exposed cervical hardware, the apparent PE diverticulum visualized in videofluoroscopy (Fig. 1) occurs due to bolus extravasation through the perforation into the retropharyngeal space. Chronic bolus extravasation leads to expansion and mucosalization posterior to the perforation within the retropharyngeal space. The resulting pseudodiverticulum is composed of a thin mucosal wall. The party wall is the posterior wall of the esophagus, inclusive of the cricopharyngeus, that has been anteriorly displaced secondary to chronic extravasation. This party wall may be diagnosed as a cricopharyngeal bar in barium studies.

A subset of Type B patients had endoscopy confirming an intact PE wall (Subjects 4–8). These diverticula appear to fall into two categories. The first category is defined by true traction diverticula, as previously hypothesized by others, that can be treated endoscopically without hardware removal [3, 6, 8, 9]. To minimize the risk of hardware exposure, we caution against overly aggressive diverticulotomy and recommend treating only the obstructive bar without opening into the retropharyngeal space. The second category is defined by true ZD and can be managed as such. For example, Subject 8 had spinal hardware and diverticulum at two separate levels, and the diverticulum was found to be a true ZD intraoperatively (Fig. 5).

Evaluation of Pharyngoesophageal Diverticula after ACSS

Barium studies of both ACSS-associated esophageal perforation with diverticulum and true ZD show contrast pooling posterior to Killian's triangle, adding to the complexity of differentiating these two entities. Although some consider videofluoroscopy (MBSS or BE) as the gold standard of diagnosing esophageal perforation, this method lacks sensitivity [26, 27]. A lateral view demonstrating contrast extravasation at the spinal hardware level and contacting the spinal hardware confirms perforation (e.g., Subject 2, Fig. 1). However, the

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absence of this finding does not rule out perforation (e.g., Subject 3, Fig. 2). Esophageal perforation and exposed hardware should always be suspected in a patient with ACSS-associated diverticulum. This dictum is exemplified by one institutional study in which 45.5% (5/11) of patients presenting with ACSS-associated dysphagia were found to have esophageal perforation with exposed hardware [2]. Therefore, endoscopic evaluation is needed to definitively exclude perforation. In-office TNE is particularly useful in dysphagia assessment, as patients can be immediately counseled regarding staged management if an esophageal perforation is found.

Management

Surgical management of the diverticulum depends on the presence and exposure of spinal hardware (Fig. 6). If spinal hardware is present and exposed within the esophageal lumen, it must be removed. Hardware removal is required to eliminate the source of pressure necrosis and infection [18, 23]. If hardware is present but not exposed, the hardware may be left in place and a simple but judicious endoscopic diverticulotomy may be performed to manage dysphagia (Type B, Subjects 4–8). Similarly, if hardware is not present, endoscopic diverticulotomy may be performed for definitive management (Type C).

Esophageal perforation repair should be performed concurrently with hardware removal. After primary perforation repair, locoregional flap placement is necessary to provide support for adequate healing [7, 26]. Primary repair without reinforcement increases healing time and time to oral intake [27]. Repair without reinforcement also increases the risk of esophageal leakage requiring revision surgery or secondary open esophageal repair [13, 16]. The sternocleidomastoid muscle (SCM) flap or the pectoralis major myocutaneous flap are commonly used [28]. The SCM is preferred for its location and appropriate size, which allows for easier advancement to and bolstering of the retropharyngeal space. The SCM flap is highly pliable, has a multi-focal blood supply, lacks significant donor site morbidity, and results in good cosmetic outcomes [27]. A gastric tube should be placed at the time of hardware removal and esophageal perforation repair for alimentation until the perforation has healed. The gastric tube can be removed at the time of interval endoscopic diverticulectomy.

Endoscopic diverticulotomy is efficacious to manage diverticula occurring after hardware removal or where hardware removal is not necessary (Fig. 6). Nearly all previously reported diverticula (90%) were managed with open diverticulectomy but the majority underwent concurrent hardware removal during open approach (Table 2). If hardware is not present, then endoscopic approach is preferred because the scar tissue and lack of surgical planes encountered in a transcervical approach increases surgical complexity and postoperative complications such as esophageal fistula [21]. Our endoscopic diverticulotomy approach uses a CO_2 laser to divide the party wall. The endoscopic approach also avoids reported issues of stapler diverticulotomy, including difficulty engaging stapler due to thick party wall fibrosis [16]. We describe the successful management of all 13 subjects with transoral CO_2 laser diverticulotomy following hardware removal with uncomplicated postoperative courses. In contrast, reported open diverticulotomy complications included unilateral vocal fold paralysis and salivary fistula (Table 2) [4, 6]. Additionally, our patients demonstrated

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long-term improvement in both videofluoroscopic findings and endoscopic swallowing evaluation.

We found that ACSS-associated diverticulum frequently requires a staged approach to adequately treat the party wall. The staged approach first involves removal of exposed cervical hardware and esophageal perforation repair, followed by definitive endoscopic diverticulotomy after esophageal healing. Staged surgery was required because the initial repair (hardware removal, esophageal perforation repair, and SCM flap placement) was unable to address the party wall adequately or the diverticulum recurred after repair. This diverticulum party wall could be managed definitively with endoscopic diverticulotomy. This approach was needed in two patients in whom we performed the hardware removal and esophageal repair (Types A and B), as well as in all patients who presented after hardware removal and repair at an outside hospital (Type C).

A small number of our patients underwent partial epiglottidectomy for epiglottic dysfunction. In three subjects (Subjects 4, 7, 8) in whom hardware removal was not indicated, significant vallecular residue was present. One additional subject (Subject 12) demonstrated vallecular residue after removal of cervical hardware elsewhere. Partial epiglottidectomy was performed in these cases, as we have shown previously that this surgery improves postswallow vallecular residue and functional swallow outcomes in those with cervical spine pathology [29].

Three novel cases of esophago-esophageal fistula (EEF) originating from the base of an ACSS-associated diverticulum was encountered (Subjects 3, 9, 11). In all cases, the EEF drained into the esophageal lumen a few centimeters distal to its origin. Our evaluation demonstrated that these fistulae often transport a small amount of the bolus, which fully clears from the EEF and drains into the esophagus. The challenges and complications of attempting EEF repair, as detailed the clinical history of Subject 9, were deemed too aggressive for a fistula that did not contribute to symptomatology or increase risk of aspiration. We found that observation of EEF is the best management, as the EEF is a mucosalized tract, asymptomatic, and not associated bolus stasis.

In this study, we present a single institution with ACSS-associated pharyngoesophageal diverticula. We excluded ACSS patients who were treated for esophageal perforations but did not present with PE diverticulum. These patients tend to present early in the disease course, when sufficient time has not passed for traction diverticulum development. Therefore, these patients did not have a significant party wall or luminal defects and were successfully managed with a transcervical approach to the spine, hardware removal, repair of the perforation, and SCM flap placement to bolster the repair. The appropriate surgical management of PE diverticulum in the setting of ACSS has been determined by experiential reports. The low number of patients presenting with this condition precludes more robust research.

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Conclusion

The presentation of pharyngoesophageal diverticula after anterior cervical spine surgery (ACSS) varies widely. We present the largest case series of successful evaluation and management of pharyngoesophageal diverticula associated with ACSS. Pharyngoesophageal diverticula co-occurring with anterior cervical hardware must be evaluated as perforations. If a perforation is present, the treatment of such diverticula must include spinal hardware removal. In such cases, we recommend a two-stage approach to the management, first a transcervical approach to remove spinal hardware and concurrent primary repair of esophageal perforation bolstered with a rotational advancement flap such as a sternocleidomastoid flap, followed by endoscopic diverticulotomy to take down the party wall. Finally, we report three new cases of esophago-esophageal fistula co-occurring with ACSS-associated diverticula that were managed by observation.

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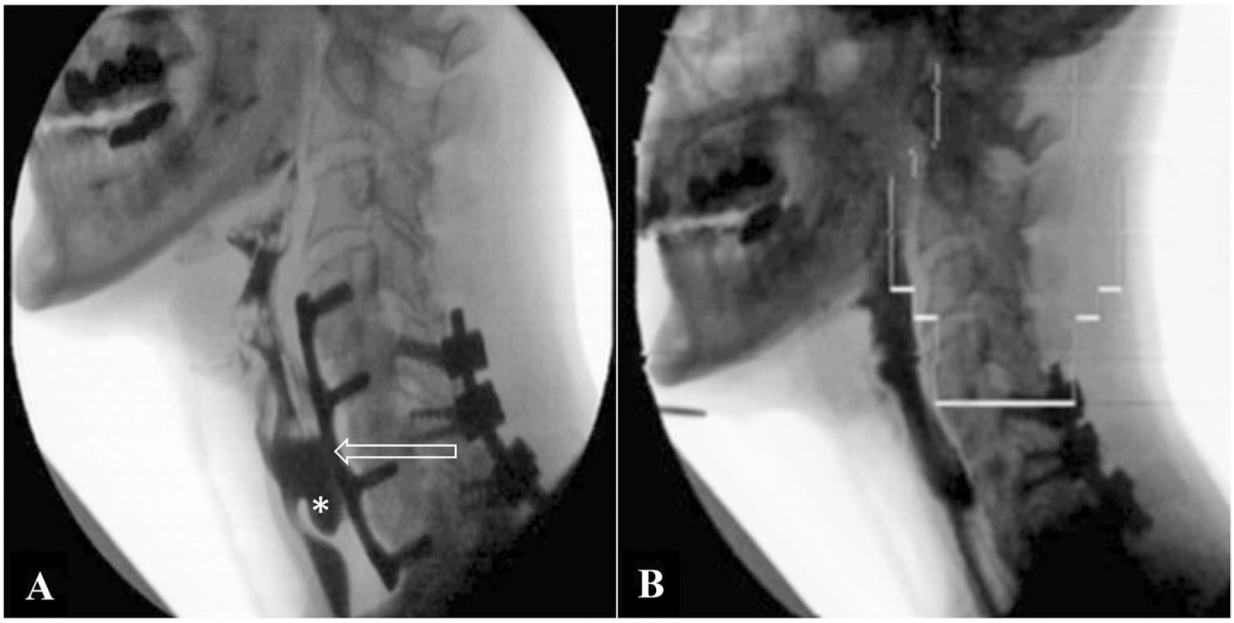

Fig. 1.

An illustrative case of a Type A presentation. **a** Modified barium swallow study demonstrating barium pooling in the pharyngoesophageal pouch (*) and contacting the cervical hardware (arrow), indicating esophageal perforation. **b** Resolution of pharyngoesophageal diverticulum after cervical hardware removal, sternocleidomastoid flap placement, and interval endoscopic diverticulotomy

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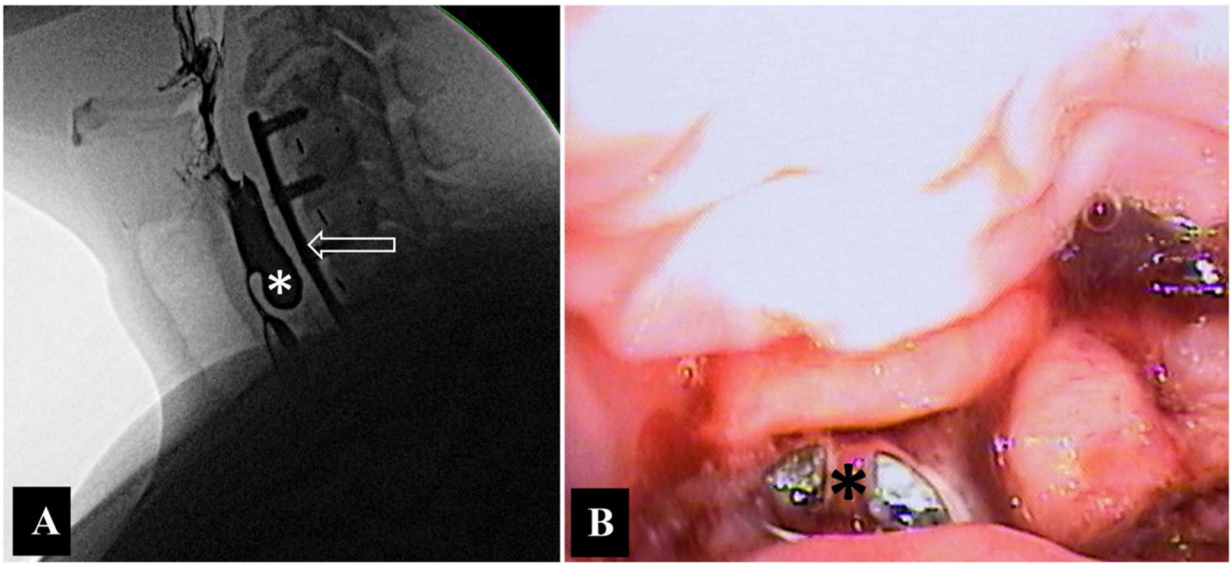

Fig. 2.

An illustrative case of a Type B Presentation. **a** Modified barium swallow study demonstrates that barium does not contact the cervical hardware (arrow), but pools in a diverticulum (*). **b** Intraoperative rigid esophagoscopy of this patient demonstrated exposed cervical hardware (*) confirming esophageal perforation. Esophagoscopy must be performed to evaluate for esophageal perforation in patients with previous anterior cervical spine surgery who present with apparent “diverticulum” on videofluoroscopic swallow studies

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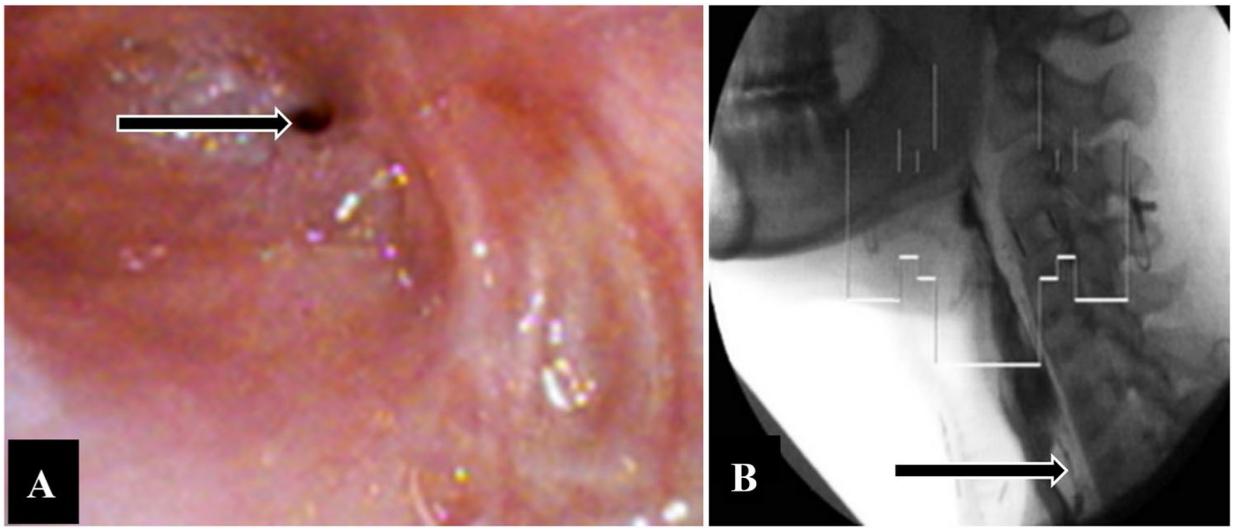

Fig. 3.

An illustrative case of a Type C, D Presentation. **a** In-office transnasal esophagoscopy (TNE) shows a pharyngoesophageal diverticulum with an opening to an esophago-esophageal fistula (arrow) located at the base of the diverticulum. **b** Modified barium swallow study after endoscopic diverticulotomy shows persistent esophago-esophageal fistula (arrow) located posteriorly to the true esophageal lumen

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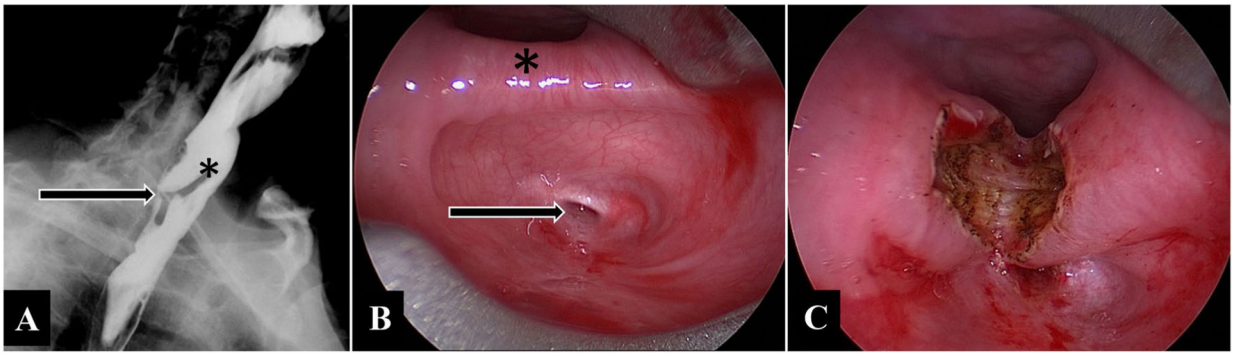

Fig. 4.

An illustrative case of a Type C, D Presentation. **a** Barium esophagram demonstrating an esophago-esophageal fistula (arrow) originating at the base of the pharyngoesophageal diverticulum. There appears to be an apparent “cricopharyngeal (CP) bar” (*). **b** Intraoperative view of the esophago-esophageal fistula (arrow) located at the base of the diverticulum. A CP bar (*) separates the diverticulum from the esophageal lumen. **c** Endoscopic diverticulotomy using the CO_2 laser. The party wall of the pharyngoesophageal diverticulum is divided with the laser to achieve the diverticulotomy

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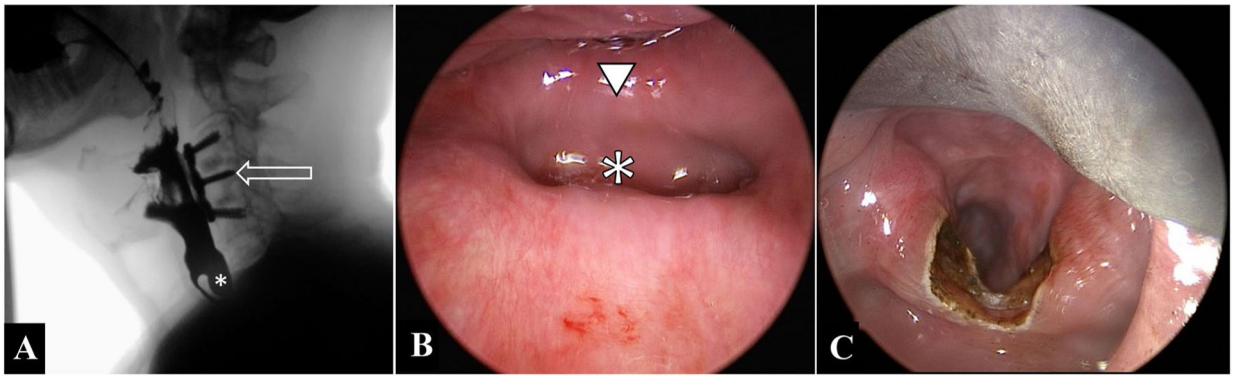

Fig. 5.

An illustrative case of a true Zenker's diverticulum occurring in a patient with previous anterior cervical spine surgery. **a** Modified barium swallow study demonstrating barium pooling in a pharyngoesophageal pouch (*) at a level lower than the cervical hardware (arrow). **b** Intraoperative view showing a cricopharyngeal bar (triangle) separating the diverticulum (*). **c** Endoscopic diverticulotomy using the CO_2 laser. The party wall of pharyngoesophageal diverticulum has been divided to achieve the diverticulotomy

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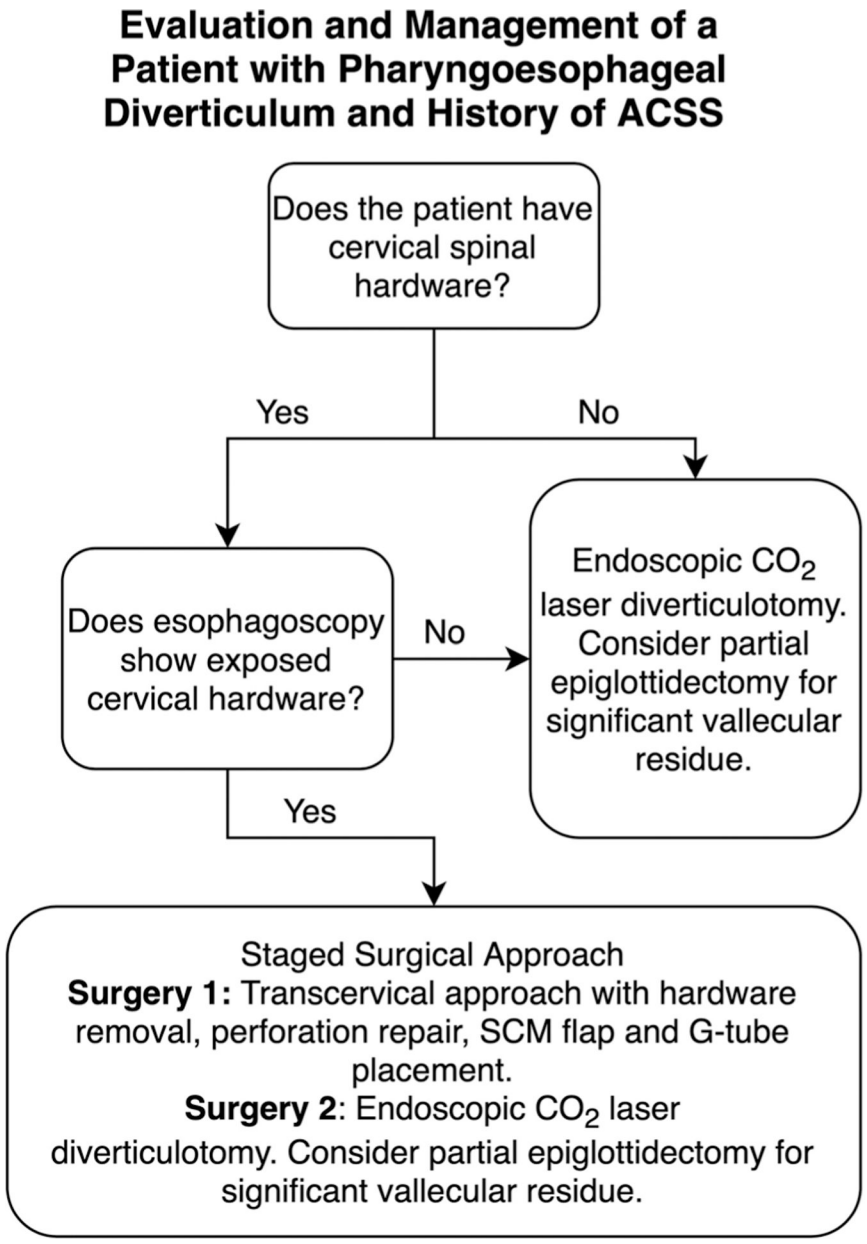

Fig. 6.

Flowchart illustrating evaluation and management of patients with a history of anterior cervical spine surgery presenting with a pharyngoesophageal diverticulum on barium studies. *ACSS* Anterior cervical spine surgery, *G-tube* gastrostomy tube, *SCM* sternocleidomastoid muscle

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Table 1

Case series from present study of patients with pharyngoesophageal diverticula after anterior cervical spine surgery

Subject No	Age/sex	Time since ACSS	Diagnosis method	Type D present	Hardware present	Hardware removed[†]	Reason hardware not removed	Flap type, if placed	Concurrent surgeries	Final approach for diverticulum	Latest follow-up and swallowing outcomes
Type A											
1	65/M	5 years	MBSS, TNE		Yes	Yes		SCM		Endoscopic	1 year, Symptom resolution, trace vallecular residue
2	69/F	10 months	MBSS, TNE		Yes	Yes		SCM		Endoscopic	5 years, Symptom resolution, trace pharyngeal residue
Type B											
3	54/F	1 year	MBSS	Yes	Yes	Yes		SCM		Endoscopic	1 year, Symptom resolution, mild pyriform sinus residue
4	62/M	5 years	MBSS, TNE		Yes	No	Not exposed		Partial epiglottidectomy	Endoscopic	5 years, Symptom resolution, trace pharyngeal residue
5	72/M	Unk	MBSS, TNE		Yes	No	Spacers only different level			Endoscopic	5 years, Symptom resolution, trace vallecular residue
6	74/F	2 years	MBSS, TNE		Yes	No	Not exposed			Endoscopic	Lost to follow-up
7	75/M	4 years	MBSS, TNE		Yes	No	Not exposed		Partial epiglottidectomy	Endoscopic	2 years, Symptom resolution, mild pharyngeal residue
8	75/M	4 years	MBSS		Yes	No	Hardware and diverticula at different levels		Partial epiglottidectomy	Endoscopic	2 years, Symptom resolution
Type C											
9	46/F	5 years	MBSS, TNE	Yes	No	N/A				Endoscopic	5 years, Symptom resolution, trace pharyngeal residue
10	49/M	Unk	MBSS, TNE		No	N/A				Endoscopic	3 years, Symptom resolution, mild vallecular residue
11	56/F	5 years	MBSS, TNE	Yes	No	N/A				Endoscopic	1 year, Symptom resolution, moderate vallecular residue

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Subject No	Age/sex	Time since ACSS	Diagnosis method	Type D present	Hardware present	Hardware removed†	Reason hardware not removed	Flap type, if placed	Concurrent surgeries	Final approach for diverticulum	Latest follow-up and swallowing outcomes
12	61/M	2 years	MBSS, TNE		No	N/A			Partial epiglottidectomy	Endoscopic	7 years. Symptom resolution, trace pharyngeal residue
13	74/M	31 years	MBSS, TNE		No	N/A				Endoscopic	3 years. Symptom resolution, mild vallecular residue

†Hardware removal as part of our management of case

ACSS Anterior cervical spine surgery, *MBSS* modified barium swallow study, *TNE* transnasal esophagoscopy, *N/A* not applicable, *SCM* sternocleidomastoid, *Unk* unknown

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Table 2

Literature review of pharyngoesophageal diverticula associated with anterior cervical spine surgery

Article	Age/sex	Time since ACSS	Presenting symptoms	Diagnosis method	Hardware removed[†]	Flap type, if placed	Final approach for diverticulum	Postoperative course and swallowing outcomes
Type A								
Sood et al. [10]	45/M	13 years	D	BE	Yes		Open	Symptom resolution, follow-up time unknown
Summers et al. [3]	43/F	2 years	D, O, F	XR, CT,BE	Yes		Open	Postoperative death secondary to mediastinitis
Alexander et al. [11]	50/F	6 years	D, R	BE	Yes	SCM	Endoscopic	Minimal dysphagia, follow-up time unknown
Joanes and Belinchon [8]	31/M	3 years	D, R, weight loss, cough	BE	Yes		Open	Symptom resolution at 3 years
Reboll Ferrer et al. [12]	35/M	2 years	D, R, globus, cough	CT	Yes		Open	Not reported
Solerio et al. [13]	41/M	7 years	F, neck swelling with fistula	XR, CT, BE	Yes	SCM	Open	Salivary fistula, second surgery with sternocleidomastoid flap, oral intake after fistula closed
Allis et al.[4] [4]	56/F	1 year	D, R, choking	BE	Yes	Myofascial	Open	Symptom resolution at 32 months
Tian et al. [14]	31/M	7 years	D, O, F, weight loss	XR, CT, BE	Yes	Sternohyoid/ Omohyoid	Open	Symptom resolution at 2.5 years
Almre et al. [15]	53/M	18 years	D	BE	Yes		Open	Suspected esophageal leak, symptom resolution at 1 year
Sadrizedah et al. [9]	24/M	2.5 years	D, O	BE	Yes		Open	Asymptomatic, follow-up time unknown
Sadrizedah et al. [9]	46/F	7 years	D, postprandial chest pain, halitosis	BE	Yes		Open	Symptom resolution at 3 months
Type B								
Ba et al. [16]	28/F	Not reported	D, O	BE	No		Open	Esophageal leak requiring second open repair on POD 21; oral diet one month later
Kau et al. [17]	22/M	4 years	D	BE	Yes	Pectoralis major	Open	Symptom resolution at 1 months
Al-Khudari et al. [18]	70/M	2 years	D	BE	Yes	Forearm fascia	Open	Esophageal perforation at 35 months postoperatively, requiring open approach revision surgery
Park et al. [7]	54/F	3 years	D, neck irritation	BE	No		Open	Negative pressure wound therapy used 7 days postoperatively; oral intake status unknown

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Article	Age/sex	Time since ACSS	Presenting symptoms	Diagnosis method	Hardware removed†	Flap type, if placed	Final approach for diverticulum	Postoperative course and swallowing outcomes
Dobran et al. [19]	45/F	1 year	F, cervical and brachial pain	MRI, CT	Yes	Sternohyoid	Open	Recurrent diverticulum, with diverticulectomy/diverticulopexy under evaluation
Volkow-Fernandez et al. [20]	48/F	4 years	D, halitosis, purulent sputum production	XR, BE, PET	Yes		Open	Symptom resolution at 4 months
Type C								
Goffart et al. [6]	44/M	8 months	D, R, weight loss	BE	N/A		Open	Intermittent food sticking at 18 months, unilateral vocal fold paralysis
Salam and Cable [21]	36/F	1.5 years	D	BE	N/A		Endoscopic	Symptom resolution at 3 months
Ba et al. [16]	63/M	6 months	D, R, globus	BE	N/A		Open	Oral intake without difficulty at POD 9
Allis et al. [4]	59/F	2 years	D.R	BE	N/A		Open	Symptom resolution at 13 months

† Hardware removal as part of management of case

ACSS Anterior cervical spine surgery, *BE* barium esophagram, *CT* computed tomography, *N/A* not applicable, *MRI* magnetic resonance imaging, *PET* positron emission tomography, *POD* postoperative day, *XR* X-ray. Presenting Symptoms: *D* Dysphagia, *O* odyngophagia, *F* fever, *R* regurgitation

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