Chapter

Dysphagia Following Anterior Cervical Spine Surgery

Ghazwan Hasan and Oscar L. Alves

Abstract

Dysphasia is regarded as one of the common complications following anterior cervical discectomy and fusion, the reported incidence varies widely and is depending on several factors, such as smoking, multi levels, anterior plating, we will discuss historical review, pathogenesis, epidemiology, clinical presentation including presentation including perioperative and postoperative recommendation and will end up with different stops and tricks to decrease this complication, in each topics we will review the evidence based articles.

Keywords: dysphagia, ACDF, cervical plating anterior cervical spine surgery

1. Introduction

Surgical approaches to the cervical spine include anterior, posterior, trans-oral, lateral trans-mandibular which can be done by open, tubular MIS or full endoscopic as described recently.

Anterior cervical spine surgery is commonly performed for the treatment of varieties of cervical spine pathologies that include degenerative, trauma, tumors, deformities and infections [1].

Techniques of anterior cervical spine surgery include anterior cervical discectomy and fusion (ACDF), anterior cervical corpectomy and fusion (ACCF), for primary stability and fusion different type of devices are used, such as cages, plates, cylinders, as well as bone growth promoters, substitutes, and bone morphogenic protein (BMP) have been use. In selected cases, discectomy alone is also performed especially through MIS or endoscopic techniques [2].

Anterior cervical discectomy and fusion (ACDF) was first described by Smith Robinson in 1968, when he performed discectomy and fusion was done using tricortical bone graft, during 1990s more than 500,000 anterior cervical discectomy and fusion (ACDF) was done in USA [3].

Anterior cervical spine surgery is safe and effective harboring a wide range of indications with a low rate of morbidity and mortality [4]. Complications following anterior cervical spine surgery include airway complications, dysphagia, dysphonia, infection, implant failure, non-union, neurological deficit, vascular injuries, implant subsidence, adjacent level disease and even death [5–10].

Dysphagia is one of the most common complications following anterior cervical spine surgeries, dysphagia is a symptom indicative of an abnormality in the neural control of, or the structures involved in, any phase of the swallowing process, which involve both voluntary and involuntary/reflex responses. Oropharyngeal dysphagia is an impairment in the speed and/or safe delivery of food materials from entry in the mouth to the upper portion of the esophagus. If present, the patient is at an increased risk of

aspiration and may be unable to swallow properly liquids, foods, or saliva. The condition is considered long standing if it is still present more than 4 weeks after surgery [11].

Dysphagia following anterior cervical surgery can occur in the three phases of swallowing process (oral & transport phase, pharyngeal & esophageal) [12].

2. Incidence and prevalence

Postoperative dysphagia is the most common complications following ACSS, the incidence ranges between 1 and 79% [1, 11, 13]. The criteria used to define and detected dysphagia may influence the reported incidence, many factors impact the exact incidence which include:

- The severity of dysphagia (mild, moderate, or severe), most of the cases fortunately presents with mild dysphagia.
- Timing of postoperative detection (immediate postoperative <2 weeks, 2 weeks, 4–6 weeks, 8–12 weeks). The earlier the detection the higher the incidence [14, 15].
- Measurement tools (repeated questionnaires or patients self-reported). The repeated questioning provides a higher incidence than self-reported [16–18].
- Surgical Techniques & Approaches (Revision, ACSS, PCSS, Standalone cage, Cervical Plate, ACDF, ACCD, & Single vs. multilevel) Revision, ACSS, multilevel surgery, cervical plating, ACCD are associated with a higher incidence [19].
- Type and design of the study & sample size (retrospective or prospective, no. of the patients in the study, and the presence of control group or not). most of the studies are no controlled retrospective in nature with an intrinsic inability to detect preoperative swallowing difficulties, with no control group [20], the higher sample size the less incidence [21].

The incidence ranges between 28 and 57% in the intermediate and long term postoperative period (1–6 weeks), [17, 22], Riley et al. on a multicentric study that enrolled 454 patient who underwent ACSS in a multicentric study between 1998 and 2001 found that the incidence of postoperative dysphagia was 28.2, 6.8 and 7.8% at 3, 6, and 24 months, respectively, and at both 6 and 24 months the prevalence rate of persistent dysphagia was 21% [21]. On another study, the average incidence varied along the post-operative time after ACSS: 53.2% at 1 month, 31.6% at 2–4 months, 19.8% at 6 months, 16.8% at 12 months and 12.9 at 24 months [11].

Lee et al. reported an overall prevalence rate of postoperative dysphagia over time as the following: 54.0% at 1 month; 33.6% at 2 months; 18.6% at 6 months; 15.2% at 1 year; and 13.6% at 2 years [19].

Later, Riley et al. in a systematic review found that the incidence of postoperative dysphagia decreased with time after surgery and reach plateau at rate of 13–21% at one year [1].

3. Natural history

Most cases of postoperative dysphagia are mild and transient, resolving gradually within 3 months [19, 23, 24] without any specific treatment. Most of the cases

of postoperative dysphagia resolve within 1 year, however, about 5–7% of cases of dysphagia after ACSS are still present 6–24 months after surgery [11].

Yue et al. reported 15% rate of dysphagia after 5 years of ACSS [24]. The predominant cause of persistent postoperative dysphagia appears to be an increase of the thickness of posterior pharyngeal wall above the upper esophageal sphincter [25].

4. Pathophysiology

Anterior cervical spine surgery impact both physiological and anatomical function of the swallowing, and these factors impact the neural, muscular & mucosal structures [19, 26]. However, in some cases dysphagia can occur in the absence of any noticed postoperative complication in anterior cervical spine surgery (ACSS).

We can summarize the etiology of dysphagia following anterior cervical spine surgery as the following:

Categories of causes	**Representative conditions**
Collagen diseases	Scleroderma, dermatomyositis
Conditions that give rise to fixed mechanical obstruction	Previous surgical treatment, tumor, cervical rings or webs, radiation/radiotherapy (pharyngeal phase)
Congenital neurologic/structural disorders/malformations	Dysautonomia, cleft palate, cerebral palsy, muscular dystrophy
Iatrogenic	Medications (chemotherapy, neuroleptics, etc.); pill injury (intentional; oral preparatory phase)
Infectious	Botulism, diphtheria, Lyme disease, mucositis (herpetic lesions, cytomegalovirus, Candida, aphthous ulcers); syphilis (oral preparatory phase)
Intrinsic functional disturbances	Cricopharyngeal achalasia, Zenker diverticulum (pharyngeal phase)
Medical	Advanced chronic obstructive pulmonary disease, deconditioning, intubation (prolonged endotracheal), rheumatoid arthritis, some viral infections
Metabolic	Amyloidosis, Cushing syndrome, thyrotoxicosis, Wilson disease
Myopathic	Connective tissue disease (overlap syndrome), myotonic dystrophy, paraneoplastic syndromes, polymyositis, sarcoidosis
Neurologic	Dementia, Guillain-Barré syndrome, Huntington disease, metabolic encephalopathies, polio, postpolio syndrome, traumatic brain injury, seizure disorders, tardive dyskinesia, brainstem tumor, cerebral vascular accident
Neuromyogenic	Myopathies (inflammatory, metabolic), parkinsonism, head trauma, stroke (oral preparatory phase and pharyngeal phase)
Progressive neurologic disorders	Dystonia, progressive supranuclear palsy, oculopharyngeal dystrophy, myasthenia gravis, amyotrophic lateral sclerosis, multiple sclerosis, Parkinson's disease (oral preparatory phase and pharyngeal phase)
Neurosurgical procedures	Aneurysm clippings, anterior cervical spine surgery; resection of tumor
Structural	Extrinsic compression, cervical osteophytes, scar tissue (oral/pharyngeal), stenosis (postsurgical/radiation/idiopathic), cricopharyngeal bar, skeletal abnormalities (pharyngeal phase)

Table 1.
Causes of oropharyngeal dysphagia according to categories, with corresponding representative conditions [11].

Approach/technique	Possible resulting condition
Operative approach (anterior)	
Dissection or retraction	Damage of the aerodigestive pathway; muscle and serosa injuries and edema; tissue damage with subsequent edema; bruising or laceration of tissues
	SLN injury, most at risk with surgery involving C3-C4 , which can cause laryngeal sensory impairment
	Injuries to the pharyngeal plexus or vagus nerve, glossopharyngeal nerve, or hypoglossal nerve (most at risk with surgery at or above C3)
	Dysfunction of the pharyngeal plexus, which affects the motility of the visceral wall
Dissection or retraction of the longus colli muscle	Muscle and subperiosteal bleeding; prevertebral soft tissue swelling
Retraction	Denervation of the pharyngeal plexus (involving the glossopharyngeal nerve and the pharyngeal branch of the vagus nerve)
Excessive or prolonged retraction	Dysphagia
	Esophageal edema, impingement, ischemia, denervation, re-perfusion injury
	Posterior pharyngeal wall edema, preventing a full epiglottic deflection
	Soft tissue fibrosis; soft tissue swelling; scar tissue formation
Significant tension during lateralization of the larynx (RLN most at risk with surgery involving C3–C4 and C5–T1)	RLN injury, which can cause vocal fold paresis or paralysis
RLN stretch injury and/or RLN compression injury from ET cuff compression	RLN palsy, which can cause vocal fold paresis or paralysis
Use of rh-BMP-2	Early local inflammatory response to rh-BMP-2 (dose-related)
Concurrent intraoperative traction on both the RLN and pharyngeal plexus	RLN injury
Other aspects of operative approach	
Direct esophageal injury	Impaired opening of the upper esophageal sphincter
	Localized denervation of portions of the esophagus and hypopharynx
	Pharyngeal wall ischemia
Hemostatic or coagulopathy	Hematoma formation
Operative technique	
Use of instrumentation	Any mechanical irritation or impingement against the esophagus
	Differences in postoperative cervical kyphotic-lordotic deformity
Thickness or anterior profile of anterior cervical plates and instrumentation	Irritation and inflammation
Plate on the esophagus	Mass effect
Use of graft	Craft (implant) protrusion, graft extrusion or cord compression
Improper halo or collar positioning	Cervical hyperextension

Abbreviations: ET, endotracheal; rhBMP-2, recombinant human bone morphogenetic protein-2; RLN, recurrent laryngeal nerve; SLN, superior laryngeal nerve.

Table 2.
Causes of oropharyngeal dysphagia according to operative approach and operative technique.

4.1 Prevertebral soft tissue swelling

Prevertebral soft tissue swelling is result of hemorrhage or intraoperative soft tissue trauma which leads to oedema which may cause transient dysfunction of the esophageal movement by impairing the upper esophageal sphincters. Nevertheless, Kang et al. failed to find a significant correlation between the thickness of prevertebral soft tissue and the incidence of dysphagia [27, 28].

4.2 Extrinsic esophageal compression

The presence of anterior cervical osteophyte, diffuse idiopathic skeletal hyperostosis can cause dysphagia secondary to mechanical impingement of esophagus, as well as inflammation causing adhesion and fibrosis.

In ACDF with plating, the presence of a plate can contributes to the same pathophysiology cause of dysphagia. Although the concept is not yet fully established, it has been proven that a thicker cervical plate is associated with a higher incidence of dysphagia [22].

Several studies confirmed that standalone cages are associated with less incidence of dysphagia when compared with ACDF with plating. However, this conclusion is not universally accepted [29].

4.3 Esophageal retraction

Retraction of esophagus during surgery to expose the anterior cervical spine is one of the possible cause of postoperative dysphagia while some studies concluded that esophageal retraction may cause ischemia of the esophageal wall which in turn compromise the motility [12], one study failed to confirm the association between the intraoperative pressure of esophageal retraction and postoperative dysphagia [30].

4.4 Neural traction

Intraoperative nerve traction or injury is another possible cause of postoperative dysphagia. Different nerves traction will cause different esophageal segment dysphagia. For example damage or traction to Hypoglossal nerve will impact the oral phase of swallowing, while injury or traction to the connection between the pharyngeal plexus and pharyngeal muscle will impact the pharyngeal phase of swallowing. Injury of the recurrent laryngeal nerve (RLN) and superior laryngeal nerve (SLN) are both operative in the development of postoperative dysphagia, reason why a sound knowledge of their anatomy and meticulous surgical technique are essential to decrease the postoperative dysphagia [11].

Anderson et al. [11] summarized the causes of oropharyngeal dysphagia as seen in **Table 1**.

Regarding the surgical techniques, the causes of dysphagia are described in **Table 2**.

5. Risk factors

5.1 Patient-related

5.1.1 Age

Smith-Hammond et al. [20] found that older patients have an higher risk of dysphagia following ACDF, while Lee et al. [19] and Bazaz et al. [19] found the no correlation between the age and the risk of dysphagia.

5.1.2 Sex

Female gender harbors an increased risk of dysphagia following ACDF [13, 19], while other studies failed to find the association between sex and dysphagia [21, 31].

5.1.3 Smoking

Many studies found that smoking is associated with and increased the risk of dysphagia following ACDF, due to its detrimental effect on soft tissue, as well as poor surgical outcomes after ACSS [5, 32].

5.1.4 Co-morbidities

Specifically the Chronic Obstructive Pulmonary Disease (COPD) increase the risk of overall postoperative mortality and morbidities following anterior cervical spine surgery [33], many studies were found the risk of dysphagia is increase in patients with COPD following ACDF [32].

5.2 Surgery-related

5.2.1 Duration of surgery

The longer the surgical time, which happens in complex procedures or in surgeries performed by less experienced surgeons, the higher contribution to the development of dysphagia, although some studies failed conclude it.

5.2.2 Multilevel surgery

Some studies have shown that multiple levels surgeries represent a significant risk factor for dysphagia [19], however others did not find any correlation between the multilevel and risk of dysphagia [31].

5.2.3 Revision surgery

In cases of revision surgeries, the presence of scar tissue can distort the anatomy compared to index surgery, rendering esophageal injury more likely [19].

5.2.4 Implant

Depending on the surgical indications related to the pathology, the level affected and the presence of deformity, different implants are used in anterior cervical surgeries. According to his/her experience and preferences, the surgeon may use stand-alone cage, hybrid cage, cervical plating, or total disc replacement [34].

The use of cervical plate in ACDF remain a controversy issue, especially in single and two levels degenerative disc disease, but many studies support its use in more than 2 levels in degenerative spine, in trauma, tumor, infections, especially if corpectomies are advocated.

Plating has the advantage of increase fusion rate, better lordotic reconstruction, enhanced primary stability of the construct, superior disc height preservation and lower subsidence rate [35]. However these benefits come at the cost of screw

pullout, loosening of plate, hardware breakage, increase in the operative time and overall costs, and increased risk of dysphagia [34].

Total disc arthroplasty (TDR) become popularized in last decades as a motion preserving technique in the anterior cervical surgeries, avoiding the fusion and decrease the adverse effect of ACDF, in selected indications. However, studies found no difference in the risk of dysphagia when comparing between TDR and ACDF [36].

5.2.5 Bone morphogenetic protein (BMP)

Bone morphogenetic protein is used during cervical surgery to increase the fusion rate especially in cases of accrued risk of pseudoarthrosis. Some studies found that BMP may constitute a risk factor for dysphagia following ACDF as it induces inflammation and oedema which will affect the surrounding soft tissue, including the esophagus [37, 38].

5.2.6 Surgical level: several

Studies found that a high level of cervical spine surgery, such as C3-4, is associated with more dysphagia than the lower levels. In the upper cervical spine, the risk of superior laryngeal nerve injury is amplified which entails an increased risk of dysphagia. As the retropharyngeal space in the upper cervical spine is more generous than in inferior cervical spine, the soft tissue swelling will be potentially more severe [39].

5.2.7 Blood loss

Significant blood loss impacts in the overall surgical outcome and is associated with many adverse effects that includes postoperative recovery and infection rate. In fact, some studies have shown than blood loss superior to 300 ml is associated with an enhanced risk of dysphagia following ACSS [21].

6. Clinical signs & symptoms

Patients present with dysphagia due to alteration in swallowing mechanisms that include [25]:

- Increased aspiration.
- Thickening of the pharyngeal wall.
- Poorer pharyngeal constriction and peristalsis.
- Prolonged transit time.
- Reduced hyoid displacement.
- Reduced opening of the pharyngoesophageal segment opening.
- Impaired epiglottic inversion

As a result of dysphagia, patients may develop other symptoms that may include:

- Reflexive coughing or wet/gurgle voice during or right after swallowing.
- Extra effort or time needed to chew or swallow.
- Food or liquid leaking from the mouth or getting stuck in the mouth.
- Recurring pneumonia or chest congestion after eating.

Persistent & severe dysphagia may result in weight loss, dehydration, risk of aspiration pneumonia, chronic lung disease and psychological problems [40].

The presence of long-standing dysphagia should raise the suspicion of esophageal perforation and thus be adamantly investigated.

7. Assessment and evaluation

7.1 Patient-reported outcome

Non-validated questionaries to evaluate the severity of dysphagia following ACSS include:

7.1.1 Bazaz dysphagia questionnaire

Depending on liquid and/or solid food difficulty swelling, they graded the severity into none, mild, moderate, and severe, as described in **Table 3** [13].

7.1.2 Modified Bazaz questionnaire

It is a modification of Bazaz Dysphagia Score into a ten-points scale recorded daily for four days, with dysphagia being defined as a cumulative four-day score of ≥12 [30] . As seen in **Table 4**.

Severity of dysphagia	Difficulty swallowing liquids	Difficulty swallowing solids
None	None	None
Mild	None	Rare
Moderate	None or rare	Occasionally (only with specific foods)
Severe	None or rare	Frequent (majority of solids)

Table 3.
Bazaz dysphagia scoring system [2].

Points	Severity of dysphagia	Definition
0	None	No episodes of difficulty swallowing
1–3	Mild	Only rare episodes of difficulty swallowing
4–6	Moderate	Occasional swallowing difficulty with solid foods
7–10	Severe	Swallowing difficulty with solids and liquids

Table 4.
Modified Bazaz dysphagia scoring system [15]. Assessment is undertaken on the day of operation and on the first, third and fifth post-operative days; the scores are added together, with dysphagia defined as a cumulative score of ≥ 12.

7.1.3 Dysphagia numerical rating scale

Assess the postoperative dysphagia using numeric scale [31].

7.1.4 Dysphagia disability index

Includes also physical function and emotional domains [31].

7.1.5 Swallowing-quality of life (SWAL-QOL) questionnaire

Swallowing-quality of life (SWAL-QOL) questionnaire is a validated 93-item questionnaire that quantifies dysphagia on the basis of severity and duration as well as its psychological impact [32], although it is has been shown to be valid and reliable, its length and complexity make it less practical in the clinical setting.

7.2 Videoflouroscopic swallow evaluation (VSE)

Videoflouroscopic swallow evaluation (VSE) is a gold standard for the assessment of swallowing impairment also referred to as a modified barium swallow study [41].

8. Treatment

The aim of treatment in postoperative dysphagia following ACSS is to maximize the food transit, minimize or prevent respiratory aspiration and related adverse effect [42].

Currently there is no specific treatment for dysphagia, as many patients with postoperative dysphagia will resolve with time. The available treatment include behavioral, postural changes, sensory input enhancement, swallowing maneuvers, voluntary control in effort exerted during swallowing and diet modification [43].

The best form of treatment is prevention, as discussed in the next section.

For persistent dysphagia that extends for more than 12–18 months, some authors recommend surgical treatment to debride the adhesion or anterior cervical instrumentation to immobilize the spine to avoid esophagus tethering and traction [44].

9. Prevention

Many studies evaluated the techniques and recommendation to decrease the incidence of postoperative dysphasia following ACSS.

9.1 Steroid therapy

The intra-operative local application of steroids in is regarded as a preventive measure to abort the development of postoperative dysphagia. This is based on the pathogenesis, as soft tissue swelling, and local inflammation will be decrease when the steroids are used. In this respect the use of IV Methylprednisolone is recommended [45], while the local application of triamcinolone in the retropharyngeal space may decrease the incidence of dysphagia postoperatively [46].

9.2 Endotracheal tube pressure

Excessive endotracheal tube pressure may impact locally by increasing transmural pressure translating in a putative risk of soft tissue injury and dysphagia development following ACSS, Accordingly, some authors recommend decreasing the endotracheal tube pressure to 20 mmHg during the period of cervical traction [47], or the release of the endotracheal tube pressure and reinflate it after retractor placement to minimize the pressure related damage to the RLN [48].

9.3 Cervical plate design

A plate can cause postoperative dysphagia due to mass effect or induction of inflammation, plate redesign to a low profile by decreasing its thickness will endure a minimization of postoperative dysphagia [22]. Equally, the use of a zero profile cage and plate or hybrid cage has shown a smaller incidence of postoperative dysphagia [49].

9.4 Tracheal traction exercises

The concept behind the preoperative tracheal traction exercise is to increase the compliance of the esophagus, thereby reducing the pressure required by retraction to expose an adequate operative field, the exercises were performed twice daily (15 times each time) for three days, starting four days before the operation [50].

9.5 Surgical techniques

An effort to limit the operative time should be undertaken to decrease the postoperative dysphagia. Appropriate surgical training should focus on acquiring a sound knowledge of anatomical variation of the RLN & SLN, a meticulous plan by plan surgical dissection, control of blood loss to better identify anatomical structures, avoid excessive blade retraction to reduce mechanical transmural esophageal pressure and anchoring the blades under the dissected longus coli to avoid injury to RLN and SLN [11, 48, 51].

10. Conclusion

Dysphagia following anterior cervical spine surgery is a common complication, in most cases it is mild and resolved with time, no specific treatment is required.

There are risk factors to increase the risk that include multiple levels, smoking, cervical plating, increase the operative time, revision surgeries.

Conflict of interest

The authors declare no conflict of interest.

Author details

Ghazwan Hasan[1*] and Oscar L. Alves[2]

1 Royal Private Hospital, Baghdad, Iraq

2 Department of Neurosurgery, Centro Hospitalar de Vila Nova de Gaia, Porto, Portugal

*Address all correspondence to: dr.bayaty@gmail.com

References

[1] Riley LH 3rd, Vaccaro AR, Dettori JR, Hashimoto R. Postoperative dysphagia in anterior cervical spine surgery. Spine (Phila Pa 1976). 2010;**35**(Suppl. 9): S76-S85

[2] Quillo-Olvera J, Lin GX, Kim JS. Percutaneous endoscopic cervical discectomy: A technical review. Annals of Translational Medicine. 2018; **6**(6):100

[3] Angevine PD, Arons RR, McCormick PC. National and regional rates and variation of cervical discectomy with and without anterior fusion, 1990-1999. Spine (Phila Pa 1976). 2003;**28**(9):931-939; discussion 40

[4] Wang H, Meng Y, Liu H, Wang X, Hong Y. The impact of smoking on outcomes following anterior cervical fusion-nonfusion hybrid surgery: A retrospective single-center cohort study. BMC Musculoskeletal Disorders. 2021;**22**(1):612

[5] Hasan GARH, Al-Naser LM, Sheta RA. Early complications of anterior cervical discectomy and fusion: A case series. Journal of Musculoskeletal Surgery and Research. 2018;**2**:121-125

[6] Fountas KN, Kapsalaki EZ, Nikolakakos LG, Smisson HF, Johnston KW, Grigorian AA, et al. Anterior cervical discectomy and fusion associated complications. Spine (Phila Pa 1976). 2007;**32**(21):2310-2317

[7] Cheung ZB, Gidumal S, White S, Shin J, Phan K, Osman N, et al. Comparison of anterior cervical discectomy and fusion with a stand-alone interbody cage versus a conventional cage-plate technique: A systematic review and meta-analysis. Global Spine Journal. 2019;**9**(4): 446-455

[8] Kashkoush A, Mehta A, Agarwal N, Nwachuku EL, Fields DP, Alan N, et al. Perioperative neurological complications following anterior cervical discectomy and fusion: Clinical impact on 317,789 patients from the national inpatient sample. World Neurosurgery. 2019;**128**:e107-ee15

[9] Wewel JT, Kasliwal MK, Adogwa O, Deutsch H, O'Toole JE, Traynelis VC. Fusion rate following three- and four-level ACDF using allograft and segmental instrumentation: A radiographic study. Journal of Clinical Neuroscience. 2019;**62**:142-146

[10] Narain AS, Hijji FY, Haws BE, Khechen B, Kudaravalli KT, Yom KH, et al. Risk factors for medical and surgical complications after 1-2-level anterior cervical discectomy and fusion procedures. International Journal of Spine Surgery. 2020;**14**(3):286-293

[11] Anderson KK, Arnold PM. Oropharyngeal dysphagia after anterior cervical spine surgery: A review. Global Spine Journal. 2013;**3**(4):273-286

[12] Mendoza-Lattes S, Clifford K, Bartelt R, Stewart J, Clark CR, Boezaart AP. Dysphagia following anterior cervical arthrodesis is associated with continuous, strong retraction of the esophagus. The Journal of Bone and Joint Surgery. American Volume. 2008;**90**(2):256-263

[13] Bazaz R, Lee MJ, Yoo JU. Incidence of dysphagia after anterior cervical spine surgery: A prospective study. Spine (Phila Pa 1976). 2002;**27**(22): 2453-2458

[14] Tervonen H, Niemelä M, Lauri ER, Back L, Juvas A, Räsänen P, et al. Dysphonia and dysphagia after anterior cervical decompression. Journal of Neurosurgery. Spine. 2007;**7**(2):124-130

[15] Vaidya R, Carp J, Sethi A, Bartol S, Craig J, Les CM. Complications of anterior cervical discectomy and fusion using recombinant human bone morphogenetic protein-2. European Spine Journal. 2007;**16**(8):1257-1265

[16] Danto J, DiCapua J, Nardi D, Pekmezaris R, Moise G, Lesser M, et al. Multiple cervical levels: Increased risk of dysphagia and dysphonia during anterior cervical discectomy. Journal of Neurosurgical Anesthesiology. 2012;**24**(4):350-355

[17] Edwards CC 2nd, Karpitskaya Y, Cha C, Heller JG, Lauryssen C, Yoon ST, et al. Accurate identification of adverse outcomes after cervical spine surgery. The Journal of Bone and Joint Surgery. American Volume. 2004;**86**(2):251-256

[18] Cho SK, Lu Y, Lee DH. Dysphagia following anterior cervical spinal surgery: A systematic review. Bone & Joint Journal. 2013;**95-b**(7): 868-873

[19] Lee MJ, Bazaz R, Furey CG, Yoo J. Risk factors for dysphagia after anterior cervical spine surgery: A two-year prospective cohort study. The Spine Journal. 2007;**7**(2):141-147

[20] Smith-Hammond CA, New KC, Pietrobon R, Curtis DJ, Scharver CH, Turner DA. Prospective analysis of incidence and risk factors of dysphagia in spine surgery patients: Comparison of anterior cervical, posterior cervical, and lumbar procedures. Spine (Phila Pa 1976). 2004;**29**(13):1441-1446

[21] Riley LH 3rd, Skolasky RL, Albert TJ, Vaccaro AR, Heller JG. Dysphagia after anterior cervical decompression and fusion: Prevalence and risk factors from a longitudinal cohort study. Spine (Phila Pa 1976). 2005;**30**(22):2564-2569

[22] Lee MJ, Bazaz R, Furey CG, Yoo J. Influence of anterior cervical plate design on Dysphagia: A 2-year prospective longitudinal follow-up study. Journal of Spinal Disorders & Techniques. 2005;**18**(5):406-409

[23] Kasimatis GB, Panagiotopoulos E, Gliatis J, Tyllianakis M, Zouboulis P, Lambiris E. Complications of anterior surgery in cervical spine trauma: An overview. Clinical Neurology and Neurosurgery. 2009;**111**(1):18-27

[24] Yue WM, Brodner W, Highland TR. Persistent swallowing and voice problems after anterior cervical discectomy and fusion with allograft and plating: A 5- to 11-year follow-up study. European Spine Journal. 2005;**14**(7):677-682

[25] Leonard R, Belafsky P. Dysphagia following cervical spine surgery with anterior instrumentation: Evidence from fluoroscopic swallow studies. Spine (Phila Pa 1976). 2011;**36**(25): 2217-2223

[26] Pattavilakom A, Seex KA. Results of a prospective randomized study comparing a novel retractor with a Caspar retractor in anterior cervical surgery. Neurosurgery. 2011;**69** (2 Suppl Operative):ons156-ons160; discussion ons60

[27] Frempong-Boadu A, Houten JK, Osborn B, Opulencia J, Kells L, Guida DD, et al. Swallowing and speech dysfunction in patients undergoing anterior cervical discectomy and fusion: A prospective, objective preoperative and postoperative assessment. Journal of Spinal Disorders & Techniques. 2002;**15**(5):362-368

[28] Kang SH, Kim DK, Seo KM, Kim KT, Kim YB. Multi-level spinal fusion and postoperative prevertebral thickness increase the risk of dysphagia after anterior cervical spine surgery. Journal of Clinical Neuroscience. 2011;**18**(10):1369-1373

[29] Chin KR, Eiszner JR, Adams SB Jr. Role of plate thickness as a cause of dysphagia after anterior cervical fusion. Spine (Phila Pa 1976). 2007;**32**(23): 2585-2590

[30] Papavero L, Heese O, Klotz-Regener V, Buchalla R, Schröder F, Westphal M. The impact of esophagus retraction on early dysphagia after anterior cervical surgery: Does a correlation exist? Spine (Phila Pa 1976). 2007;**32**(10):1089-1093

[31] Rihn JA, Kane J, Albert TJ, Vaccaro AR, Hilibrand AS. What is the incidence and severity of dysphagia after anterior cervical surgery? Clinical Orthopaedics and Related Research. 2011;**469**(3):658-665

[32] Siska PA, Ponnappan RK, Hohl JB, Lee JY, Kang JD, Donaldson WF 3rd. Dysphagia after anterior cervical spine surgery: A prospective study using the swallowing-quality of life questionnaire and analysis of patient comorbidities. Spine (Phila Pa 1976). 2011;**36**(17): 1387-1391

[33] Malik AT, Jain N, Kim J, Khan SN, Yu E. Chronic obstructive pulmonary disease is an independent predictor for 30-day complications and readmissions following 1- to 2-level anterior cervical discectomy and fusion. Global Spine Journal. 2019;**9**(3):298-302

[34] Viswanathan VK, Manoharan SR. To plate or not to plate after a single- or two-level anterior cervical discectomy: Fusion with cage-plate construct or stand-alone cage. Asian Spine Journal. 2017;**11**(1):1-3

[35] Song KJ, Taghavi CE, Lee KB, Song JH, Eun JP. The efficacy of plate construct augmentation versus cage alone in anterior cervical fusion. Spine (Phila Pa 1976). 2009;**34**(26):2886-2892

[36] Anderson PA, Nassr A, Currier BL, Sebastian AS, Arnold PM, Fehlings MG, et al. Evaluation of adverse events in total disc replacement: A meta-analysis of fda summary of safety and effectiveness data. Global Spine Journal. 2017;**7**(Suppl. 1):76s-83s

[37] Buttermann GR. Prospective nonrandomized comparison of an allograft with bone morphogenic protein versus an iliac-crest autograft in anterior cervical discectomy and fusion. The Spine Journal. 2008;**8**(3):426-435

[38] Ozgursoy OB, Salassa JR, Reimer R, Wharen RE, Deen HG. Anterior cervical osteophyte dysphagia: Manofluorographic and functional outcomes after surgery. Head & Neck. 2010;**32**(5):588-593

[39] Liu F-Y, Yang D-L, Huang W-Z, Huo L-S, Ma L, Wang H, et al. Risk factors for dysphagia after anterior cervical spine surgery: A meta-analysis. Medicine. 2017;**96**(10):e6267

[40] Cook IJ, Kahrilas PJ. AGA technical review on management of oropharyngeal dysphagia. Gastroenterology. 1999;**116**(2):455-478

[41] Martin-Harris B, Brodsky MB, Michel Y, Castell DO, Schleicher M, Sandidge J, et al. MBS measurement tool for swallow impairment—MBSImp: Establishing a standard. Dysphagia. 2008;**23**(4):392-405

[42] Cook IJ. Diagnostic evaluation of dysphagia. Nature Clinical Practice. Gastroenterology & Hepatology. 2008;**5**(7):393-403

[43] Logemann JA, Larsen K. Oropharyngeal dysphagia: Pathophysiology and diagnosis for the anniversary issue of diseases of the esophagus. Diseases of the Esophagus. 2012;**25**(4):299-304

[44] Fogel GR, McDonnell MF. Surgical treatment of dysphagia after anterior cervical interbody fusion. The Spine Journal. 2005;**5**(2):140-144

[45] Pedram M, Castagnera L, Carat X, Macouillard G, Vital JM. Pharyngolaryngeal lesions in patients undergoing cervical spine surgery through the anterior approach: Contribution of methylprednisolone. European Spine Journal. 2003; **12**(1):84-90

[46] Lee SH, Kim KT, Suk KS, Park KJ, Oh KI. Effect of retropharyngeal steroid on prevertebral soft tissue swelling following anterior cervical discectomy and fusion: A prospective, randomized study. Spine (Phila Pa 1976). 2011; **36**(26):2286-2292

[47] Ratnaraj J, Todorov A, McHugh T, Cheng MA, Lauryssen C. Effects of decreasing endotracheal tube cuff pressures during neck retraction for anterior cervical spine surgery. Journal of Neurosurgery. 2002;**97**(Suppl. 2): 176-179

[48] Apfelbaum RI, Kriskovich MD, Haller JR. On the incidence, cause, and prevention of recurrent laryngeal nerve palsies during anterior cervical spine surgery. Spine (Phila Pa 1976). 2000;**25**(22):2906-2912

[49] Scholz M, Schnake KJ, Pingel A, Hoffmann R, Kandziora F. A new zero-profile implant for stand-alone anterior cervical interbody fusion. Clinical Orthopaedics and Related Research. 2011;**469**(3):666-673

[50] Chen Z, Wei X, Li F, He P, Huang X, Zhang F, et al. Tracheal traction exercise reduces the occurrence of postoperative dysphagia after anterior cervical spine surgery. Spine (Phila Pa 1976). 2012;**37**(15):1292-1296

[51] Razfar A, Sadr-Hosseini SM, Rosen CA, Snyderman CH, Gooding W, Abla AA, et al. Prevention and management of dysphonia during anterior cervical spine surgery. The Laryngoscope. 2012;**122**(10):2179-2183