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REVIEW

Risk factors and preventative measures of early and persistent dysphagia after anterior cervical spine surgery: a systematic review

Jingwei Liu[1] · Yong Hai[1] · Nan Kang[1] · Xiaolong Chen[1] · Yangpu Zhang[1]

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Abstract
Purpose To conduct a systematic review of literature to determine risk factors and preventative measures of early and persistent dysphagia after anterior cervical spine surgery (ACSS).
Methods On March 2017, we searched the database PubMed, Medline, EMBASE, the Cochrane library, Clinical key, Springer link and Wiley Online Library without time restriction using the term 'dysphagia', 'swallowing disorders', and 'anterior cervical spine surgery'. Selected papers were examined for the level of evidence by published guidelines as level I, level II, level III, level IV studies. We investigated risk factors and preventative measures of early or persistent dysphagia after ACSS from these papers.
Results The initial search yielded 515 citations. Fifty-nine of these studies met the inclusion and exclusion criteria. Three of them were level I evidence studies, 29 were level II evidence studies, 22 were level III evidence studies, and 3 were level IV evidence studies. Preventable risk factors included prolonged operative time, use of rhBMP, endotracheal tube cuff pressure, cervical plate type and position, dC2–C7 angle, psychiatric factors, tobacco usage, prevertebral soft tissue swelling, SLN or RLN palsy or injury of branches. Preventative measures included preoperative tracheal traction exercise, maintaining endotracheal tube cuff pressure at 20 mm Hg, avoiding routine use of rhBMP-2, use of zero-profile implant, use of Zephir plate, use of new cervical retractor, steroid application, avoiding prolonged operating time, avoiding overenlargement of cervical lordosis, decreasing surgical levels, ensuring knowledge of anatomy of superior laryngeal nerve and recurrent laryngeal nerve, to comfort always, patients quitting smoking and doctors ensuring improved skills. Unpreventable risk factors included age, gender, multilevel surgery, revision surgery, duration of preexisting pain, BMI, blood loss, upper levels, preoperative comorbidities and surgical type.
Conclusion Adequate preoperative preparation of the patients including preoperative tracheal traction exercise and quitting smoking, proper preventative measures during surgery including maintaining endotracheal tube cuff pressure at 20 mm Hg, avoiding routine use of rhBMP-2, use of zero-profile implant, use of Zephir plate, use of new cervical retractor, steroid application, avoiding prolonged operating time, avoiding overenlargement of cervical lordosis and decreasing surgical levels, doctors ensuring knowledge of anatomy, improved surgical techniques and to comfort always are essential for preventing early and persistent dysphagia after ACSS.

Keywords Anterior cervical spine surgery · Dysphagia · Risk factors · Preventative measures · Systematic review

Introduction

Anterior cervical spine surgery (ACSS) is commonly used for the treatment of numerous cervical disorders, such as traumatic, degenerative and congenital diseases [1, 2]. Dysphagia is one of the most common complications after ACSS that occurs frequently. Previous studies observed that dysphagia easily occurred in the early postoperative stage with reported incidence of up to 88%, and its symptoms were particularly serious in the early phase [1, 3–6]. Persistent

✉ Yong Hai
jason358liu@126.com

[1] Department of Orthopedics, Beijing Chao-Yang Hospital, Capital Medical University, GongTiNanLu 8#, Chao-Yang District, Beijing 100020, China

dysphagia could lead to not eating or drinking normally and troubled the patients for a long time [38]. Knowing risk factors and preventative measures of early and persistent dysphagia after ACSS become an important work for the spine surgeons when doing the procedure.

Materials and methods

In March 2017, we searched the database PubMed, Medline, EMBASE, the Cochrane library, Clinical key, Springer link and Wiley Online Library without time restriction using the terms ‘dysphagia’, ‘swallowing disorders’ and ‘anterior cervical spine surgery’ looking for papers published in English that reported risk factors and preventative measures of early or persistent dysphagia after anterior cervical spine surgery.

The search produced a total of 515 published articles (Fig. 1). Abstracts were reviewed and included if dysphagia was a reported patient outcome measure and if the study investigated risk factors and prevention of early or persistent dysphagia after ACSS. Exclusion criteria included case reports, case series, reviews, commentaries, and cadaveric or experimental studies in animals. Fifty-nine articles including 32 prospective and 27 retrospective studies were included in this systematic review (Table 1). Level of evidence ratings were assigned to each article independently by two reviewers (J. L., N. K.) using published guidelines [69].

Results

We evaluated 59 studies, three of them were level I evidence studies, 29 were level II evidence studies, 22 were level III evidence studies, and 3 were level IV evidence studies. Preventable risk factors and preventative measures are described in Table 2. Unpreventable risk factors are described in Table 3. The evaluated articles are described in the following.

Preventable risk factors and preventative measures

Prolonged operative time

Twelve studies investigated whether prolonged operated time was a risk factor for early or persistent dysphagia. Four studies including two prospective and two retrospective studies observed it as a risk factor, while eight studies including three prospective and five retrospective studies did not find a significant correlation.

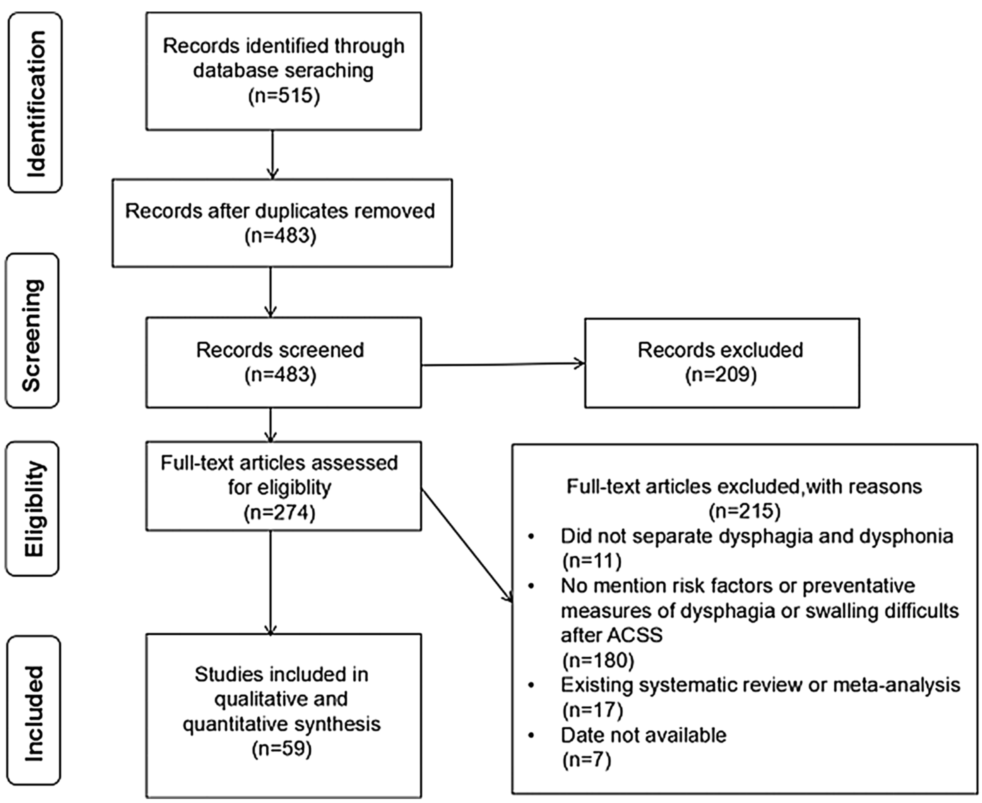

Fig. 1 PRISMA (preferred reporting items for systematic reviews) flow diagram for selection of studies based on inclusion criteria during systematic review

Table 1 Studies included in the systematic review

Authors	Study type	Sample size	Level of evidence
Arts et al. [57]	Prospective double-blind randomized controlled trail	177	I
Bazaz et al. [10]	Prospective longitudinal cohort	224	II
Burkus et al. [21]	Prospective comparative cohort	710	II
Buttermann et al. [19]	Prospective longitudinal	66	II
Carucci et al. [52]	Retrospective longitudinal	74	III
Chen et al. [35]	Retrospective longitudinal	30	IV
Chen et al. [58]	Prospective randomized controlled	102	II
Chin et al. [28]	Prospective comparative cohort	63	II
Cole et al. [17]	Retrospective comparative	91,543	III
Danto et al. [48]	Retrospective longitudinal	149	III
Edwards et al. [56]	Prospective randomized placebo-controlled double-blind trial	50	I
Fehlings et al. [39]	Prospective Multicenter	302	II
Fengbin et al. [51]	Prospective randomized controlled trial	80	II
Fineberg et al. [16]	Retrospective longitudinal	2337552	III
Hofstetter et al. [31]	Retrospective cohort	70	III
Jain et al. [18]	Retrospective comparative	1,064,372	III
Jang et al. [65]	Retrospective longitudinal	50	III
Jeyamohan et al. [61]	Prospective double-blind randomized controlled trail	112	I
Kalb et al. [5]	Retrospective longitudinal	249	III
Kang et al. [36]	Prospective longitudinal cohort	72	II
Kang et al. [9]	Retrospective longitudinal	45	IV
Kepler et al. [40]	Prospective longitudinal cohort	43	II
Kowalczyk et al. [26]	Prospective randomized control pilot	50	II
Leckie et al. [50]	Retrospective longitudinal	1269	III
Lee et al. [27]	Prospective comparative	156	II
Lee et al. [11]	Prospective longitudinal cohort	310	II
Lee et al. [42]	Prospective randomized controlled	50	II
Liu et al. [1]	Prospective longitudinal cohort	104	II
Liu et al. [32]	Retrospective comparative	60	III
Lovasik et al. [12]	Retrospective longitudinal cohort	191	III
Lu et al. [20]	Retrospective longitudinal	150	III
McAfee et al. [53]	Prospective randomized	251	II
Mehra et al. [47]	Retrospective longitudinal	188	III
Mendoza-lattes [24]	Prospective longitudinal	17	II
Miao et al. [29]	Prospective comparative cohort	89	II
Nam et al. [43]	Prospective randomized controlled	62	II
Netterville et al. [45]	Retrospective longitudinal	289	III
Njoku et al. [66]	Retrospective longitudinal	41	IV
Olsson et al. [38]	Prospective cross-sectional cohort	100	II
Papavero [25]	Prospective longitudinal cohort	92	II
Pattavilakom et al. [23]	Prospective randomized controlled	26	II
Pedram et al. [62]	Prospective comparative cohort	236	II
Qi et al. [30]	Retrospective cohort	190	III
Ratnaraj et al. [22]	Prospective randomized controlled	51	II
Reinard et al. [67]	Retrospective longitudinal	94	III
Rihn et al. [7]	Prospective comparative	94	II
Riley et al. [8]	Retrospective longitudinal	454	III
Shi et al. [34]	Prospective comparative	112	II
Singh et al. [4]	Retrospective comparative	159,590	III

Table 1 (continued)

Authors	Study type	Sample size	Level of evidence
Siska et al. [37]	Prospective comparative	29	II
Smith-Hammond et al. [15]	Prospective comparative cohort	83	II
Song et al. [41]	Prospective randomized controlled	40	II
Suk et al. [60]	Prospective longitudinal cohort	87	II
Tervonen et al. [44]	Retrospective cohort	114	III
Tian et al. [13]	Retrospective longitudinal	452	III
Tian et al. [14]	Retrospective longitudinal	454	III
Tumialan et al. [68]	Retrospective longitudinal	200	III
Wu et al. [49]	Retrospective longitudinal	358	III
Zeng et al. [3]	Retrospective longitudinal	186	III

Liu et al. [1] found that operative time is the risk factor for dysphagia during the first day ($p = 0.009$) to the second day ($p = 0.017$) after ACSS. Kalb et al. [5] found that operative time tended to be longer in those who developed dysphagia (186 vs 169 min). Rihn et al. [7] also found a correlation between operative time and the severity of dysphagia after 12 weeks of one- or two-level anterior cervical decompression and fusion (ACDF) in their prospective study ($p = 0.04$). Riley et al. [8] reported in a retrospective analysis that the risk of persistent dysphagia increased as the duration of surgery increased after ACDF.

On the other hand, some studies [3, 9–15] failed to find prolonged operative time to be a significant risk factor.

Use of BMP

There are two forms of BMP: recombinant human BMP-2 (rhBMP-2) and BMP-7 [16]. Three prospective and six retrospective studies relating the use of BMP and dysphagia after ACSS were found.

Cole et al. [17] found that rhBMP use was associated with an increased risk of dysphagia within 30 days postoperatively (OR = 1.3, 95% CI 1.1–1.5). Jain et al. [18] also found that use of rhBMP was significantly associated with the development of dysphagia after ACSS [prevalence, 2.0%; adjusted odds radio (OR), 1.53]. Fineberg et al. [16] also observed a significantly higher rate of dysphagia when BMP was utilized during ACDF (37.2 vs 22.5 per 1000 cases; $p < 0.0005$). Buttermann et al. [19] concluded that the use of BMP did result in increased dysphagia of patients who had primary one- to three-level ACDF with iliac-crest bone autograft. Lu et al. [20] also found the use of rhBMP-2 significantly increased the severity of dysphagia in patients undergoing 2-level ACDF ($p < 0.005$). Burkus et al. [21] observed high rates of dysphagia at 24 months after single-level allograft when rhBMP-2 was used ($p = 0.001$).

Lovasik et al. [12] found no difference in dysphagia incidence between rhBMP-2 or beta-tricalcium phosphate (bTCP) groups of patients who underwent ACDF with polyetheretherketone plastic fusion spacers during a 2-year period in their retrospective study (20 vs 17%, $p = 0.5$).

Endotracheal tube cuff pressure and cervical retractors

Five prospective studies investigated whether endotracheal tube cuff pressure was a risk factor for early and persistent dysphagia after ACSS. Three of them considered endotracheal tube cuff pressure (ETCP) as a risk factor and suggested decreasing ETCP or using dynamic retractors to prevent dysphagia after ACSS.

Ratnaraj et al. [22] reported that an increased ECTP during neck retraction and a prolonged retraction time were risk factors of postoperative dysphagia at 24 h ($p < 0.05$, $r^2 = 0.61$). They suggested that decreasing ETCP to 20 mmHg may be helpful in improving patient comfort following ACSS. Pattavilakom et al. [23] performed a prospective randomized clinical trail to compare the conventional Cloward-style retractor (CRS) with a novel seek retractor system (SRS) after 1- to 2-level ACDF. This study found that average retraction pressure and mean average peak retraction pressure with SRS were all lower than that with CRS ($p < 0.001$). Mendoza-lattes [24] reported that patients with dysphagia had a significantly higher average intraluminal pressure as well as significantly lower average mucosal perfusion secondary to retraction ($p < 0.0001$). They suggested that dynamic retraction associates with a lower prevalence of postoperative dysphagia.

Although three level II evidence studies investigated endotracheal tube cuff pressure as a risk factor of early and persistent dysphagia after ACSS, there were still two studies that did not find a correlation between them. Papavero et al. [25] found no correlation between the amount of retraction and early postoperative dysphagia after ACSS in their

Table 2 Preventable risk factors and preventative measures of early dysphagia after anterior cervical spine surgery

Preventable risk factors	Preventative measures	Supporting studies (study type, level of evidence)
Prolonged operative time	Avoid a prolonged operative time Improve surgical technique	Liu et al. [1] (prospective, level II) Kalb et al. [5] (retrospective, level III) Rihn et al. [7] (prospective, level II) Riley et al. [8] (retrospective, level III)
Use of rhBMP	Avoid routine use of rhBMP Local depomedrol application	Lovasik et al. [12] (retrospective, level III) Edwards et al. [56] (prospective, level I) Burkus et al. [21] (prospective, level II) Cole et al. [17] (retrospective, level III) Jain et al. [18] (retrospective, level III) Fineberg et al. [16] (retrospective, level III) Lu et al. [20] (retrospective, level III) Buttermann et al. [19] (prospective, level II)
Endotracheal tube cuff pressure	Decrease endotracheal tube cuff pressure New cervical retractors TTE	Arts et al. [57] (prospective, level I) Ratnaraj et al. [22] (prospective, level II) Pattavilakom et al. [23] (prospective, level II) Mendoza-lattes [24] (prospective, level II) Chen et al. [58] (prospective, level II)
Cervical plate type and position	Use smaller and smoother plates Zero-profile implant	Kepler et al. [40] (prospective, level II) Lee et al. [27] (prospective, level II) Zeng et al. [3] (retrospective, level III) Liu et al. [32] (retrospective, level III) Qi et al. [30] (retrospective, level III) Miao et al. [29] (prospective, level II) Hofstetter et al. [31] (retrospective, level III)
dC2–C7 angle	Avoid overenlargement of cervical lordosis	Liu et al. [1] (prospective, level II) Tian et al. [13] (retrospective, level III) Chen et al. [35] (retrospective, level IV) Shi et al. [34] (prospective, level II)
Psychiatric factors	To comfort always	Kang et al. [36] (prospective, level II)
Tobacco usage	Quit smoking	Olsson et al. [38] (prospective, level II) Siska et al. [37] (prospective, level II)
Prevertebral soft tissue swelling	Steroid application	Kang et al. [9] (retrospective, level IV) Riley et al. [8] (retrospective, $n = 454$) Jeyamohan et al. [61] (prospective, level I) Lee et al. [42] (prospective, level II) Pedram et al. [62] (prospective, level II) Song et al. [41] (prospective, level II) Kepler et al. [40] (prospective, level II) Shi et al. [34] (prospective, level II) Suk et al. [60] (prospective, level II)
SLN or RLN palsy or injury of branches	Ensure knowledge of anatomy of SLN and RLN	Tervonen et al. [44] (retrospective, level III) Netterville et al. [45] (retrospective, level III)

Table 3 Unpreventable risk factors of early dysphagia after anterior cervical spine surgery

Unpreventable risk factors
Old age
Female gender
Multilevel surgery
Revision surgery
Higher BMI
ACDF VS cervical disk replacement
Duration of preexisting pain
Preoperative comorbidities
Upper levels

prospective study. Kowalczyk et al. [26] found decreasing ETCP to 15 mm Hg during surgery had no effect on the prevalence of dysphagia after ACSS ($p > 0.05$).

Use of plating, plate profile and prominence

Four studies including two prospective and two retrospective studies investigated whether using cervical plate or plate profile and position correlated with early or persistent dysphagia after ACSS. Five studies suggested using Zero-P implant and one study suggested using smaller and smoother profile plate to prevent early and persistent dysphagia.

Zeng et al. [3] observed that use of plate was one of the risk factors of early dysphagia after ACSS ($p = 0.012$). They also found a bigger protrusion about 1.4 mm in the dysphagia group ($p < 0.001$). Lee et al. [27] suggested that the use of a smaller and smoother profile plate does reduce the incidence of early and persistent dysphagia after ACSS.

But Jain et al. [18] and Chin et al. [28] failed to find a correlation between plate profile or prominence and postoperative dysphagia.

Miao et al. [29] performed a prospective study to analyze the primary efficacy and safety of a new zero-profile implant (Zero-P) in Chinese population compared with a control group of patients using anterior titanium plate. The authors reported similar clinical and radiographic outcomes of the two groups. But the incidence of dysphagia was lower and the symptom duration was much shorter in the Zero-P group. Three other studies [30–32] also found that using Zero-P can reduce the incidence of early dysphagia in their retrospective studies, whereas Vanekn et al. [33] didn't find significant difference in the incidence of dysphagia between Zero-P interbody spacer and standard interbody spacer.

dC2–C7 angle

The C2–C7 angle was defined as the angle between the lines parallel to the inferior end plate of C2 and C7 vertebral bodies (Cobb's method). dC2–C7 angle = postoperative C2–C7 angle – preoperative C2–C7 angle [14]. Three studies including two prospective and one retrospective studies investigated dC2–C7 angle as a risk factor of early or persistent dysphagia after ACSS.

Liu et al. [1] found that the dC2–C7 angle significantly associated with early dysphagia from the third to the fifth day after ACSS and when the dC2–C7 angle was greater than 9°, the incidence of dysphagia was significantly increased ($p < 0.05$). Two other studies [13, 34] also found that when the dC2–C7 angle was greater than 5°, the chance of developing dysphagia was significantly greater. Furthermore, Chen et al. [35] found that dC2–C7 angle was also a risk factor for combined anterior–posterior cervical spine surgery ($p = 0.020$).

Psychiatric factors

Kang et al. [36] performed a prospective study to identify associations between psychiatric factors and the development of dysphagia 1 year after single-level ACDF. Multivariate logistic regression showed that the psychiatric problem prior to surgery was the risk factor of persistent dysphagia ($p = 0.005$). They suggested that patients with a psychiatric factor should be counseled before surgery.

But Riley et al. [8] did not find significant relationship between psychiatric factors and dysphagia at 6 and 12 months after ACSS ($p > 0.05$).

Tobacco usage

Two prospective studies considered tobacco usage as a risk factor of early or persistent dysphagia after ACSS. Siska et al. [37] analyzed that increased degree of dysphagia was associated with tobacco usage 3 weeks after surgery ($p = 0.002$). Olsson et al. [38] found that the increased prevalence of dysphagia in smokers (38 vs 21%) trended toward statistical significance and the severity of dysphagia was more severe for smokers ($p = 0.02$).

There are still three other studies [3, 5, 39] that did not find a correlation between tobacco usage and postoperative dysphagia.

Prevertebral soft tissue swelling

Shi et al. [34] reported prevertebral soft tissue swelling (PSTS) change greater than 5 mm was prone to have early postoperative dysphagia ($p = 0.000$). Riley et al. [8] also found PSTS relating to dysphagia after ACDF in their retrospective study.

But Kang et al. [9] observed no statistically significant difference between PSTS and dysphagia at 1, 3, and 6 months after ACSS ($p > 0.05$). Kepler et al. [40] found that the degree of dysphagia had no correlation with postoperative dysphagia after 1- to 2-level ACDF ($p > 0.05$).

Song et al. [41] and Lee et al. [42] found that prevertebral soft tissue swelling as well as postoperative dysphagia reduced significantly with steroid administration during ACSS. But Nam et al. [43] failed to find the correlation between PSTS decrease and steroid application.

SLN or RLN palsy or injury of branches

Two studies [44, 45] considered superior laryngeal nerve (SLN) or recurrent laryngeal nerve (RLN) palsy or injury of branches as risk factor for dysphagia after ACSS. Tervonen et al. [44] suggested RLN should be detected during surgery. Razfar et al. [46] suggested spine surgeons to ensure knowledge of normal and aberrant courses of the SLN and RLN.

Unpreventable risk factors

Age

Seventeen studies including 6 prospective and 11 retrospective studies investigated whether age was a risk factor. Six studies including two prospective studies [12, 15] and four retrospective studies [3, 4, 12, 39] identified old age as a risk factor. Eleven studies including four prospective studies [1, 7, 37, 38] and seven retrospective studies [8, 13, 14, 35, 47–49] did not find a significant correlation.

Gender

Eighteen studies including eight prospective and ten retrospective studies investigated whether gender was a risk factor. Six studies including five prospective studies [10, 11, 25, 28, 37] and one retrospective study [3] identified female as a risk factor and one retrospective study [4] identified male as a risk factor. Eleven studies including three prospective studies [1, 27, 39] and eight retrospective studies [8, 12–14, 35, 47–49] did not find a significant correlation.

Multilevel surgery

Fourteen studies including 3 prospective and 11 retrospective studies investigated whether multilevel surgery was a risk factor. Nine studies including one prospective study [10] and eight retrospective studies [3–5, 8, 9, 47–49] identified multilevel surgery as a risk factor. Five studies including two prospective studies [14, 27] and three retrospective studies [12, 38, 50] did not find a significant correlation.

Revision surgery

Seven studies including three prospective and four retrospective studies investigated whether revision surgery was a risk factor. Two studies including one prospective study [38] and one retrospective study [50] identified revision surgery as a risk factor. Five studies including two prospective studies [14, 27] and three retrospective studies [11, 13, 47] did not find a significant correlation.

Duration of preexisting pain

Three studies including two prospective studies and one retrospective study investigated whether duration of preexisting pain was a risk factor. Two studies including one prospective study [39] and one retrospective study [8] identified duration of preexisting pain as a risk factor, while one prospective study [38] did not find a significant correlation.

BMI

Nine studies including five prospective and four retrospective studies investigated whether higher BMI was a risk factor. Four studies including two prospective studies [11, 25] and two retrospective studies [5, 50] identified higher BMI as a risk factor. Five studies including three prospective studies [1, 7, 39] and two retrospective studies [13, 37] did not find a significant correlation.

Blood loss

Five studies including one prospective and four retrospective studies investigated whether blood loss was a risk factor. One prospective study [39] identified blood loss as a risk factor. Four retrospective studies [3, 35] did not find a significant correlation.

Upper levels

Fourteen studies including six prospective and eight retrospective studies investigated whether upper levels were a risk factor. Eight studies including two prospective studies [28, 51] and six retrospective studies [5, 9, 12, 35, 47, 49] identified upper level surgeries as a risk factor. Five studies including four prospective studies [10, 11, 37, 40] and one retrospective study [8] did not find a significant correlation.

One retrospective study [52] considered dysphagia a more common clinical problem after ACDF in the mid cervical spine.

Preoperative comorbidities

Two studies [4, 37] investigated preoperative comorbidities such as chronic lung disease and diabetes as a significant risk factor. But they did not give a suggestion whether controlling the preoperative comorbidities could reduce dysphagia after surgery. Two studies [3, 12] failed to find a relationship between preoperative comorbidities and the incidence of dysphagia.

ACDF versus cervical disk replacement

Three studies [1, 4, 53] investigated the incidence of dysphagia between ACDF and cervical disk replacement, they reported lower incidence of dysphagia in the cervical disk replacement group.

Discussion

Several risk factors may lead to early or persistent dysphagia after ACSS, some of them are unpreventable, and some of them are preventable. Although some studies had different conclusions, we do find some preventative measures to reduce postoperative dysphagia.

As we know, if the esophagus and prevertebral soft tissue were retracted for a long time during the surgery, they would be injured and result in severe swelling [40]. The swelling of esophagus and prevertebral soft tissue finally led to patient dysphagia. However, it is likely that multilevel surgeries took longer operative time than single-level surgeries [8]. It still remains controversial that whether prolonged operative time was a risk factor, but avoiding a prolonged operative time and improving surgical techniques do help to prevent dysphagia after ACSS. Avoiding a prolonged operative time could reduce the injury to the prevertebral soft tissue [1]. In complex cervical cases in which a long operative time is predicted, senior surgeons with improved surgical techniques would probably have less dysphagia after surgery than fellows and residents [54].

One of the potential mechanisms leading to dysphagia after BMP use is increasing the incidence of swelling after ACSS [55]. Therefore, spine surgeons should avoid routine use of BMP except for patients who underwent revision surgery or at high risk for pseudarthrosis. For these patients, depomedrol is supposed to be administered locally [12]. Fineberg et al. [16] recommended that if BMP is to be used in ACDF, the patients should be clinically monitored for dysphagia in the early postoperative period. Edwards et al. [56] performed a prospective randomized placebo-controlled double-blind trail and found that patients receiving depomedrol experienced decreased dysphagia incidence and magnitude at all time intervals ($p < 0.05$). This study provided level I evidence that locally administered depomedrol on a collagen sponge could significantly decrease postoperative dysphagia following ACDF using low-dose BMP-2.

Arts et al. [57] protocoled a double-blind randomized controlled trial to determine whether adjusting ETCP after placement of a retractor during ACSS would prevent postoperative dysphagia after ACSS. Recruitment of patients had started in December 2011 and would be finished at the end of 2013. The results of this level I evidence study may lead to standard adjustment of ETCP in every patient undergoing ACSS to decrease postoperative morbidity, and now we are still waiting for the result of this study. Chen et al. [58] considered that if ETCP was reduced, the surgical field would become narrow and operations would become more difficult to perform. Therefore, they designed a preoperative tracheal traction exercise (TTE) to prevent dysphagia after ACSS. The TTE was performed twice per day, 15 counts each time, for 3 days, starting 4 days before the surgery.

Anterior plating may be responsible for higher rates of early and persistent dysphagia because of the plate's mass effect on the adjacent esophagus and because contralateral screw placement requires more retraction past the midline than is necessary when a plate is not used [40]. In addition, scar tissue formation on a less smooth plate surface may lead to postoperative dysphagia [27]. Although most studies suggested using smaller and smoother plates or Zero-P implant to prevent early and persistent dysphagia after ACSS, better designed, especially level I, studies are required to clarify this issue.

The overenlargement of cervical lordosis may lead to bulging of the posterior pharyngeal wall, which may reduce pharyngeal space, and influence the normal process of pharyngeal squeeze and laryngeal elevation. Thus, overcorrecting the sagittal alignment of the cervical spine may increase the dysphagia rate [34]. Tian et al. [13] suggested that overenlargement of cervical lordosis should be avoided to reduce the development of postoperative dysphagia.

How psychiatric problem increased the incidence of dysphagia was unexplained, these patients tended to over-report their symptoms of dysphagia [36]. Further studies are required to study the relationship between psychiatric factors and dysphagia after ACSS, and patients with a psychiatric factor should be counseled before surgery as the medical ethics told "to comfort always" [59].

Although two studies observed tobacco usage as a risk factor of early and persistent dysphagia after ACSS, they did not give a suggestion to quit smoking to prevent postoperative dysphagia. Olsson et al. [38] found that there was no difference between those who never smoked and those who formerly smoked of postoperative dysphagia, which may indicate that quitting smoking could help to decrease dysphagia after ACSS. Further studies are required to determine the effect of smoking in postoperative dysphagia.

Suk et al. [60] reported the natural change of PSTS in the early postoperative period. PSTS was increased continuously from the 2nd day and reached a plateau on the 3rd day postoperatively. A gradual decrease was starting at the 4th day after surgery. Whether steroid administration can decrease PSTS remains controversial, but it could prevent and reduce early postoperative dysphagia. Four randomized controlled trails [41, 42, 61, 62], one of which is a double-blinded study [61], found that steroid administration significantly improved swallowing function and reduced dysphagia in the early postoperative period.

Haller et al. [63, 64] explained the clinical anatomy of SLN during ACSS to help us ensure knowledge of them.

Conclusion

Adequate preoperative preparation of the patients including preoperative tracheal traction exercise and quit smoking, properly preventative measures during surgery including maintaining endotracheal tube cuff pressure at 20 mm Hg, avoiding routine use of rhBMP-2, use of zero-profile implant, use of Zephir plate, use of new cervical retractor, steroid application, avoiding prolonged operating time, avoiding overenlargement of cervical lordosis and decreasing surgical levels, doctors ensuring knowledge of anatomy, improving surgical techniques and to comfort always are essential for preventing early and persistent dysphagia after ACSS.

Compliance with ethical standards

Conflict of interest None of the authors has any potential conflict of interest.

References

1. Liu JM et al (2017) The incidences and risk factors related to early dysphagia after anterior cervical spine surgery: a prospective study. PLoS One 12(3):e0173364
2. Riley LH 3rd et al (2010) Postoperative dysphagia in anterior cervical spine surgery. Spine (Phila Pa 1976) 35(9 Suppl):S76–S85
3. Zeng JH, Zhong ZM, Chen JT (2013) Early dysphagia complicating anterior cervical spine surgery: incidence and risk factors. Arch Orthop Trauma Surg 133(8):1067–1071
4. Singh K et al (2013) Incidence and risk factors for dysphagia after anterior cervical fusion. Spine (Phila Pa 1976) 38(21):1820–1825
5. Kalb S et al (2012) Dysphagia after anterior cervical spine surgery: incidence and risk factors. World Neurosurg 77(1):183–187
6. Campbell PG et al (2010) Early complications related to approach in cervical spine surgery: single-center prospective study. World Neurosurg 74(2–3):363–368
7. Rihn JA et al (2011) What is the incidence and severity of dysphagia after anterior cervical surgery? Clin Orthop Relat Res 469(3):658–665
8. Riley LH 3rd et al (2005) Dysphagia after anterior cervical decompression and fusion: prevalence and risk factors from a longitudinal cohort study. Spine (Phila Pa 1976) 30(22):2564–2569
9. Kang SH et al (2011) Multi-level spinal fusion and postoperative prevertebral thickness increase the risk of dysphagia after anterior cervical spine surgery. J Clin Neurosci 18(10):1369–1373
10. Bazaz R, Lee MJ, Yoo JU (2002) Incidence of dysphagia after anterior cervical spine surgery: a prospective study. Spine (Phila Pa 1976) 27(22):2453–2458
11. Lee MJ et al (2007) Risk factors for dysphagia after anterior cervical spine surgery: a two-year prospective cohort study. Spine J 7(2):141–147
12. Lovasik BP et al (2017) Anterior cervical discectomy and fusion: comparison of fusion, dysphagia, and complication rates between recombinant human bone morphogenetic protein-2 and beta-tricalcium phosphate. World Neurosurg 97:674
13. Tian W, Yu J (2016) The role of C2–C7 angle in the development of dysphagia after anterior and posterior cervical spine surgery. Clin Spine Surg. doi:10.1097/BSD.0000000000000493
14. Tian W, Yu J (2013) The role of C2–C7 and O–C2 angle in the development of dysphagia after cervical spine surgery. Dysphagia 28(2):131–138
15. Smith-Hammond CA et al (2004) 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) 29(13):1441–1446
16. Fineberg SJ et al (2013) Hospital outcomes and complications of anterior and posterior cervical fusion with bone morphogenetic protein. Spine (Phila Pa 1976) 38(15):1304–1309
17. Cole T et al (2014) Usage of recombinant human bone morphogenetic protein in cervical spine procedures: analysis of the MarketScan longitudinal database. J Bone Joint Surg Am 96(17):1409–1416
18. Jain A et al (2014) rhBMP use in cervical spine surgery: associated factors and in-hospital complications. J Bone Jt Surg Am 96(8):617–623
19. Buttermann GR (2008) Prospective nonrandomized comparison of an allograft with bone morphogenic protein versus an iliac-crest autograft in anterior cervical discectomy and fusion. Spine J 8(3):426–435
20. Lu DC, Tumialan LM, Chou D (2013) Multilevel anterior cervical discectomy and fusion with and without rhBMP-2: a comparison of dysphagia rates and outcomes in 150 patients. J Neurosurg Spine 18(1):43–49
21. Burkus JK et al. (2016) Clinical and radiographic outcomes in patients undergoing single-level anterior cervical arthrodesis: a prospective trial comparing allograft to a reduced dose of rhBMP-2. Clin Spine Surg. doi:10.1097/BSD.0000000000000409
22. Ratnaraj J et al (2002) Effects of decreasing endotracheal tube cuff pressures during neck retraction for anterior cervical spine surgery. J Neurosurg 97(2 Suppl):176–179
23. Pattavilakom A, Seex KA (2011) Results of a prospective randomized study comparing a novel retractor with a Caspar retractor in anterior cervical surgery. Neurosurgery 69(2 Suppl Operative):ons156–ons160 **(discussion ons160)**
24. Mendoza-Lattes S et al (2008) Dysphagia following anterior cervical arthrodesis is associated with continuous, strong retraction of the esophagus. J Bone Jt Surg Am 90(2):256–263
25. Papavero L et al (2007) The impact of esophagus retraction on early dysphagia after anterior cervical surgery: does a correlation exist? Spine (Phila Pa 1976) 32(10):1089–1093
26. Kowalczyk I et al (2015) Reduced endotracheal tube cuff pressure to assess dysphagia after anterior cervical spine surgery. J Spinal Disord Tech 28(10):E552–E558
27. Lee MJ et al (2005) Influence of anterior cervical plate design on Dysphagia: a 2-year prospective longitudinal follow-up study. J Spinal Disord Tech 18(5):406–409
28. Chin KR, Eiszner JR, Adams SB Jr (2007) Role of plate thickness as a cause of dysphagia after anterior cervical fusion. Spine (Phila Pa 1976) 32(23):2585–2590
29. Miao J et al (2013) Early follow-up outcomes of a new zero-profile implant used in anterior cervical discectomy and fusion. J Spinal Disord Tech 26(5):E193–E197
30. Qi M et al (2013) The use of a zero-profile device compared with an anterior plate and cage in the treatment of patients with symptomatic cervical spondylosis: a preliminary clinical investigation. Bone Joint J 95-b(4):543–547
31. Hofstetter CP, Kesavabhotla K, Boockvar JA (2015) Zero-profile anchored spacer reduces rate of dysphagia compared with ACDF with anterior plating. J Spinal Disord Tech 28(5):E284–E290
32. Liu Y et al (2016) Comparison of a zero-profile anchored spacer (ROI-C) and the polyetheretherketone (PEEK) cages with an anterior plate in anterior cervical discectomy and fusion for multilevel cervical spondylotic myelopathy. Eur Spine J 25(6):1881–1890
33. Vanek P et al (2013) Anterior interbody fusion of the cervical spine with Zero-P spacer: prospective comparative study-clinical and radiological results at a minimum 2 years after surgery. Spine (Phila Pa 1976) 38(13):E792–E797
34. Shi S et al (2016) Risk factors for dysphagia after single-level anterior cervical decompression with arthroplasty or fusion: a prospective study comparing 2 Zero-profile implants. World Neurosurg 95:148–155
35. Chen CJ et al (2013) Dysphagia following combined anterior-posterior cervical spine surgeries. J Neurosurg Spine 19(3):279–287
36. Kang SS et al (2014) The association between psychiatric factors and the development of chronic dysphagia after anterior cervical spine surgery. Eur Spine J 23(8):1694–1698
37. Siska PA et al (2011) 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) 36(17):1387–1391
38. Olsson EC, Jobson M, Lim MR (2015) Risk factors for persistent dysphagia after anterior cervical spine surgery. Orthopedics 38(4):e319–e323

39. Fehlings MG et al (2012) Perioperative and delayed complications associated with the surgical treatment of cervical spondylotic myelopathy based on 302 patients from the AOSpine North America Cervical Spondylotic Myelopathy Study. J Neurosurg Spine 16(5):425–432
40. Kepler CK et al (2012) Dysphagia and soft-tissue swelling after anterior cervical surgery: a radiographic analysis. Spine J 12(8):639–644
41. Song KJ et al (2014) The clinical efficacy of short-term steroid treatment in multilevel anterior cervical arthrodesis. Spine J 14(12):2954–2958
42. Lee SH et al (2011) Effect of retropharyngeal steroid on prevertebral soft tissue swelling following anterior cervical discectomy and fusion: a prospective, randomized study. Spine (Phila Pa 1976) 36(26):2286–2292
43. Nam TW et al (2013) Effect of intravenous dexamethasone on prevertebral soft tissue swelling after anterior cervical discectomy and fusion. Acta Orthop Belg 79(2):211–215
44. Tervonen H et al (2007) Dysphonia and dysphagia after anterior cervical decompression. J Neurosurg Spine 7(2):124–130
45. Netterville JL et al (1996) Vocal fold paralysis following the anterior approach to the cervical spine. Ann Otol Rhinol Laryngol 105(2):85–91
46. Razfar A et al (2012) Prevention and management of dysphonia during anterior cervical spine surgery. Laryngoscope 122(10):2179–2183
47. Mehra S et al (2014) Factors predictive of voice and swallowing outcomes after anterior approaches to the cervical spine. Otolaryngol Head Neck Surg 150(2):259–265
48. Danto J et al (2012) Multiple cervical levels: increased risk of dysphagia and dysphonia during anterior cervical discectomy. J Neurosurg Anesthesiol 24(4):350–355
49. Wu B, Song F, Zhu S (2016) Reasons of dysphagia after operation of anterior cervical decompression and fusion. Clin Spine Surg 30(5):E554–E559. doi:10.1097/BSD.0000000000000180
50. Leckie S et al (2016) Perioperative complications of cervical spine surgery: analysis of a prospectively gathered database through the association for collaborative spinal research. Global Spine J 6(7):640–649
51. Fengbin Y et al (2013) Dysphagia after anterior cervical discectomy and fusion: a prospective study comparing two anterior surgical approaches. Eur Spine J 22(5):1147–1151
52. Carucci LR, Turner MA, Yeatman CF (2015) Dysphagia secondary to anterior cervical fusion: radiologic evaluation and findings in 74 patients. AJR Am J Roentgenol 204(4):768–775
53. McAfee PC et al (2010) Lower incidence of dysphagia with cervical arthroplasty compared with ACDF in a prospective randomized clinical trial. J Spinal Disord Tech 23(1):1–8
54. Joaquim AF et al (2014) Dysphagia after anterior cervical spine surgery: a systematic review of potential preventative measures. Spine J 14(9):2246–2260
55. Vaidya R et al (2007) Complications of anterior cervical discectomy and fusion using recombinant human bone morphogenetic protein-2. Eur Spine J 16(8):1257–1265
56. Edwards CC 2nd et al (2016) Can dysphagia following anterior cervical fusions with rhBMP-2 be reduced with local depomedrol application? a prospective, randomized, placebo-controlled. Double-blind trial. Spine (Phila Pa 1976) 41(7):555–562
57. Arts MP et al (2013) Maintaining endotracheal tube cuff pressure at 20 mm Hg to prevent dysphagia after anterior cervical spine surgery; protocol of a double-blind randomised controlled trial. BMC Musculoskelet Disord 14:280
58. Chen Z et al (2012) Tracheal traction exercise reduces the occurrence of postoperative dysphagia after anterior cervical spine surgery. Spine (Phila Pa 1976) 37(15):1292–1296
59. Smith HL (1987) Medical ethics in the primary care setting. Soc Sci Med 25(6):705–709
60. Suk KS et al (2006) Prevertebral soft tissue swelling after anterior cervical discectomy and fusion with plate fixation. Int Orthop 30(4):290–294
61. Jeyamohan SB et al (2015) Effect of steroid use in anterior cervical discectomy and fusion: a randomized controlled trial. J Neurosurg Spine 23(2):137–143
62. Pedram M et al (2003) Pharyngolaryngeal lesions in patients undergoing cervical spine surgery through the anterior approach: contribution of methylprednisolone. Eur Spine J 12(1):84–90
63. Haller JM, Iwanik M, Shen FH (2011) Clinically relevant anatomy of high anterior cervical approach. Spine (Phila Pa 1976) 36(25):2116–2121
64. Haller JM, Iwanik M, Shen FH (2012) Clinically relevant anatomy of recurrent laryngeal nerve. Spine (Phila Pa 1976) 37(2):97–100
65. Jang JW, Park JH, Rhim SC (2014) Does plate profile affect postoperative dysphagia following anterior cervical spine surgery? J Clin Neurosci 21(1):78–81
66. Njoku I Jr et al (2014) Anterior cervical discectomy and fusion with a zero-profile integrated plate and spacer device: a clinical and radiological study: clinical article. J Neurosurg Spine 21(4):529–537
67. Reinard KA et al (2016) A cohort study of the morbidity of combined anterior-posterior cervical spinal fusions: incidence and predictors of postoperative dysphagia. Eur Spine J 25(7):2068–2077
68. Tumialan LM et al (2008) The safety and efficacy of anterior cervical discectomy and fusion with polyetheretherketone spacer and recombinant human bone morphogenetic protein-2: a review of 200 patients. J Neurosurg Spine 8(6):529–535
69. Wright JG, Swiontkowski MF, Heckman JD (2003) Introducing levels of evidence to the journal. J Bone Joint Surg [Am] 85:1–3