Article

Discovery Medicine 2023; 35(178): 823–830
https://doi.org/10.24976/Discov.Med.202335178.77

The Early Effects of Longus Colli Muscle and Anterior Longitudinal Ligament Reconstructions on Swallowing Function after Anterior Cervical Surgery: A Six-Month Follow-Up Study

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Published: 1 October 2023

Background: Anterior cervical discectomy and fusion (ACDF) is the gold standard surgery used to treat cervical degenerative disease. Dysphagia and hoarseness are the two most common complications that occur after anterior cervical surgery (ACS). In this study, we aim to evaluate the early effects of longus colli muscle (LCM) and anterior longitudinal ligament (ALL) reconstructions on swallowing function after ACS.

Methods: We recruited 91 patients (35 males and 56 females; mean age: 49.41 ± 8.60 years [range: 26–72 years]) who have undergone either ACDF or anterior cervical corpectomy and fusion (ACCF) between August 2019 and October 2021. Patients were divided into LCM and ALL suture group (Group A), and LCM and ALL non-suture group (Group B). Assessments of the incidence of dysphagia and the swallowing quality of life (SWAL-QOL) were completed in 2 days, 1 week, 1 month, 3 months and 6 months after surgery. Average prevertebral soft tissue thickness (APSTT) were measured on lateral cervical spine radiographs taken with X-rays 2 days, 1 month, 3 months and 6 months after surgery.

Results: In the 2-day, 1-week and 1-month postoperative follow-up, the incidence of dysphagia in group A was significantly lower than that in group B ($p < 0.05$), and the SWAL-QOL scores of group A were significantly higher than those of group B ($p < 0.05$). In the 3-month and 6-month postoperative follow-up, no significant differences were found between groups A and B in terms of the incidence of dysphagia ($p > 0.05$). In the 6-month postoperative follow-up, no significant differences were found between the groups in terms of SWAL-QOL scores ($p > 0.05$). There were no significant differences in APSTT between groups during postoperative follow-up ($p > 0.05$).

Conclusion: The reconstructions of LCM and ALL in ACS can effectively improve short-term postoperative swallowing function.

Keywords: anterior cervical surgery; anterior longitudinal ligament; longus colli muscle; dysphagia; SWAL-QOL; average prevertebral soft tissue thickness

Introduction

After being introduced by Robinson Smith, anterior cervical surgery (ACS) has become a common surgical approach to treating cervical spondylotic myelopathy (CSM) and is acclaimed for the excellent clinical outcomes [1,2]. Among the different subtypes of ACS, anterior cervical discectomy and fusion (ACDF) is the gold standard surgery used in the treatment of cervical degenerative disease [3]. Although ACDF is a common surgery that can be performed by most surgeons [4], the treated patients could suffer from postoperative complications [4–6]. Dysphagia and hoarseness are the two most common complications that occur after ACS [6], and dysphagia has an obvious impact on the postoperative life quality of patients [7,8]. Unfortunately, the causes of dysphagia after ACS remain unclear. Several studies have reported that dysphagia after ACS was caused by multiple factors, including age, sex, esophageal injury, postoperative soft tissue edema, postoperative local hematoma, peripheral tissue adhered to steel implants, the number of cervical spine surgery segments, long anesthesia and operation time, and internal fixation with titanium plate/titanium mesh [9–12].

Over the recent years, the prevention of dysphagia has been given increasing attention, and some helpful guidelines have been introduced. Some examples of dysphagia prevention methods include preoperative tracheal trac-

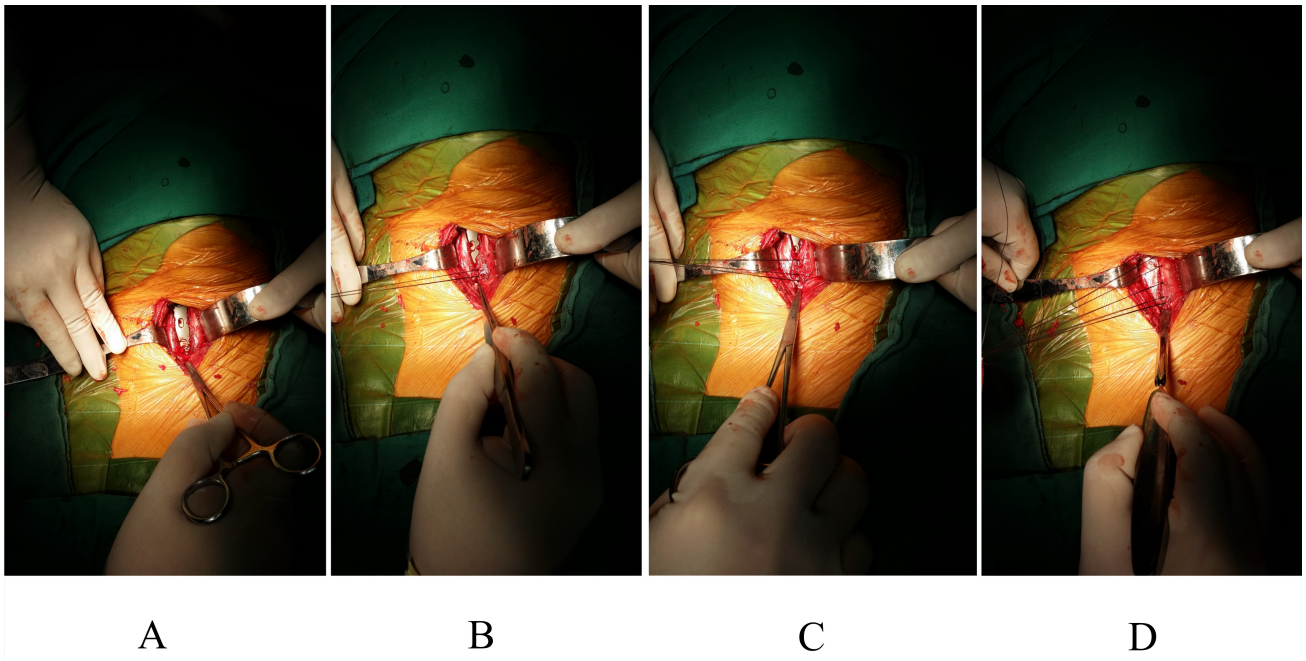

Fig. 1. Intraoperative process of suturing longus colli muscle and anterior longitudinal ligament. (A) Showed the surgical area without suturing. (B–D) Showed the changes in the surgical area as the longus colli muscle (LCM) and anterior longitudinal ligament (ALL) were gradually sutured together.

tion exercise [13], using modified retractor systems [14,15], smoking cessation prior to surgery [16], using zero-profile spacers instead of plates [17], and choosing posterior cervical foraminotomy [18]. The cervical prevertebral fascia may be sutured to prevent dysphagia after cervical spine surgery, but the soft fascia is too thin to suture [19]. Alternatively, applying absorbable collagen biomembrane after suturing the prevertebral fascia can reduce the occurrence of dysphagia after cervical spine surgery [20], but the membrane may cause local inflammation and rejection. Longus colli muscle (LCM) and anterior longitudinal ligament (ALL) are the tissues anterior to the cervical spine, and it is much more difficult to suture these tissues. The ALL is the longest ligament in the human body, and one of its functions is to sustain the stability of the spine. The LCM also can improve the stability of the cervical spine. So the reconstruction of the LCM and ALL can enhance the stability of the cervical spine. However, clinical studies evaluating the effects of reconstructions of LCM and ALL on the prevention of dysphagia after ACS remain scarce. In view of this, this study intended to evaluate the early effects of LCM and ALL reconstructions on swallowing functions after ACS.

Patients and Methods

Study Participants

Ninety-one patients who have undergone ACS (either ACDF or anterior cervical corpectomy and fusion (ACCF)) between August 2019 and October 2021 in the Department of Orthopedics of The First Affiliated Hospital of Anhui Medical University were enrolled retrospectively and followed up in this study. This study was performed in accordance with the Declaration of Helsinki. Informed consent was obtained from all patients. Every patient was followed up for 6 months, and the last follow-up was in April 2022. Among the enrolled patients, 35 patients (mean age: 47.76 $\pm$ 9.80 years; range: 26–70 years) whose LCM and ALL were sutured during ACS were categorized into group A, while 56 patients (mean age: 50.43 $\pm$ 7.61 years; range: 35–72 years) whose LCM and ALL were not sutured during ACDF were categorized into group B. This study was approved by the Medical Ethics Committee of The First Affiliated Hospital of Anhui Medical University (Quik-PJ 2022-06-63).

Inclusion and Exclusion Criteria

Inclusion Criteria

Patients with cervical degenerative disc disease, ossification of the posterior longitudinal ligament, cervical spinal stenosis and/or cervical spine fracture were included in the present study. Cervical magnetic resonance imaging (MRI) was performed on the patients to confirm the diagnosis of the above-mentioned diseases affecting segments C3 to C7. Surgery was only indicated in patients whose symptoms failed to be improved by non-surgical approaches.

Exclusion Criteria

Patients were excluded from this study if they have: (i) dysphagia symptoms or complaints prior to surgery; (ii)

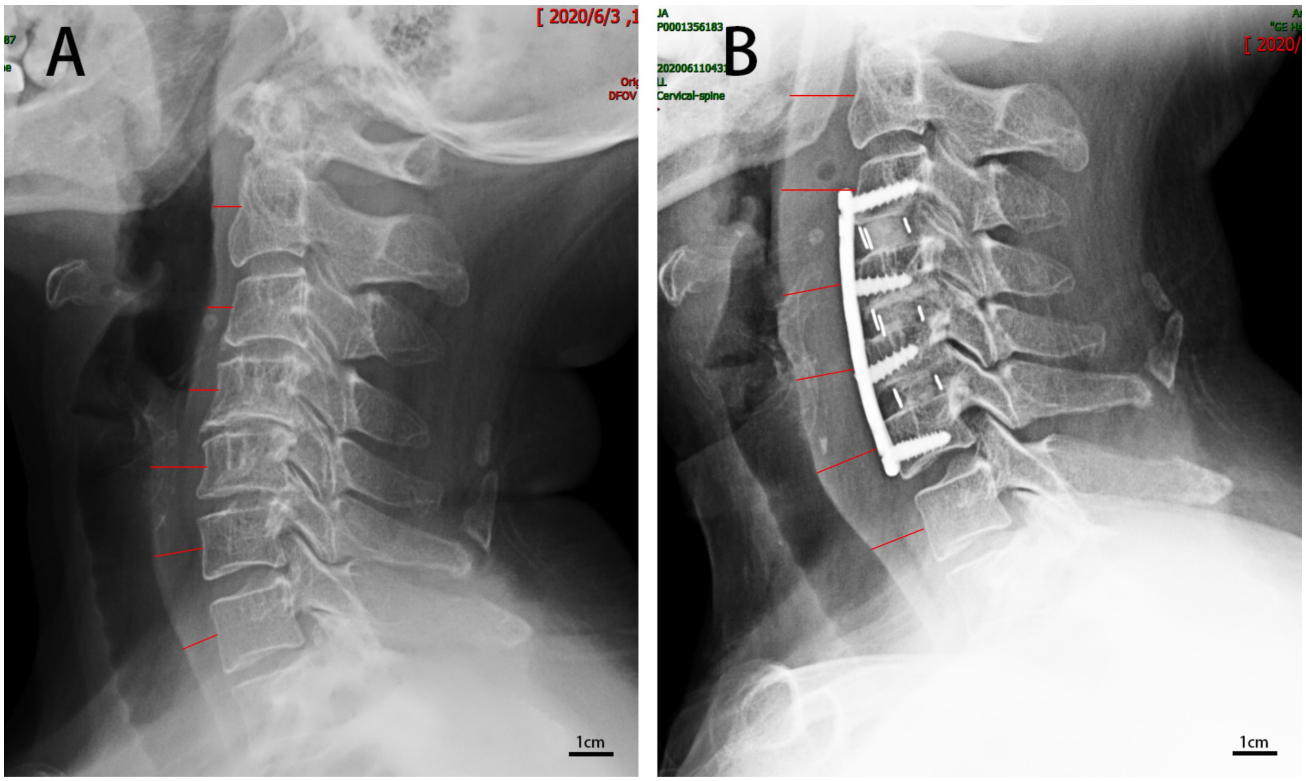

Fig. 2. The length of the prevertebral soft tissue was measured as the distance between the anterior surface of each vertebral body and the air shadow of the airway. (A) The red lines showed the distance between the anterior surface of each vertebral body and the air shadow of the airway before surgery. (B) The red lines showed the distance between the anterior surface of each vertebral body and the air shadow of the airway after surgery.

a history of cervical surgery; (iii) prior cervical spine infections, deformities, or neck masses; and (iv) other diseases that may cause dysphagia.

Surgical Procedure

All included patients were operated on by the same experienced spine surgeon, and tracheal traction exercise was not conducted prior to surgery. An electronic laryngoscope (TDC-K3, Zhejiang UE Medical Corp, Xianju, China) was used for tracheal intubation. The oral endotracheal intubation with general anesthesia was performed during the surgery (intubation depth: 22 $\pm$ 2 cm; diameter: 7.5 mm for male, 7.0 mm for female). All internal fixation devices were anterior cervical plate (FJQ-B, Beijing Fule Science & Technology Development Co., LTD, Beijing, China), which is 16 mm in width and 2 mm in thickness. S-type manual retractors (O20110, Jinzhong surgical instrument, Shanghai, China) were used to pull the trachea and esophagus during the surgery. The ACDF or ACCF techniques were performed, as previously described, using a standard anterior approach to the cervical spine [21]. After the cervical discs were totally excised and the cages and plates were installed, the medial borders of ALL and LCM of the patients in group A were sutured (Fig. 1), whereas the ALL and LCM of the patients in group B were not sutured. After that, the wounds were cleaned and closed in a standard manner. The operation time and blood loss were recorded by the anesthesiologist and surgeon, respectively.

Outcome Assessment

The primary outcomes were the incidence of dysphagia and the swallowing quality of life (SWAL-QOL), which were assessed 2 days, 1 week, 1 month, 3 months and 6 months after surgery. The secondary outcomes were the average prevertebral soft tissue thickness (APSTT) and the general clinical data.

General Clinical Data

All the relevant patient data were documented by the spine surgeon while the patients were hospitalized and followed up. The data includes age, sex, weight, height, and body mass index (BMI). BMI was calculated using the following equation: BMI = Weight (kg)/Height^2 (m^2).

Incidence of Dysphagia

The presence of dysphagia in each group was evaluated by a blinded clinical practitioner according to Bazaz's criterion [22]. The incidence of dysphagia was calculated during each follow-up.

Table 1. Characteristics of study participants in groups A and B.

Variable	Group A (n = 35)	Group B (n = 56)	χ^2/T value	*p*-value
Sex				
Male	15	22	0.114	0.736
Female	20	34		
Age	47.45 ± 9.82	50.82 ± 8.07	1.778	0.079
BMI (kg/m^2)	23.36 ± 2.31	24.13 ± 3.10	1.265	0.209
Single segment surgery (%)	28.57 (10/35)	19.64 (11/56)	0.967	0.325
Operation time (min)	78.14 ± 18.67	70.63 ± 18.61	1.872	0.064
Blood loss (mL)	23.31 ± 9.50	25.43 ± 8.52	1.079	0.283
Anesthesia time (min)	103.29 ± 24.40	106.61 ± 28.73	0.568	0.572

BMI, body mass index.

Degree of Postoperative Dysphagia

The degree of postoperative dysphagia in each group was evaluated using SWAL-QOL questionnaire [23]. The SWAL-QOL questionnaire is a validated patient-based measurement tool for assessing dysphagia, evaluating the impact of dysphagia from the patient's perspective. This questionnaire consists of 13 items; each was scored on a scale of 1 to 5, corresponding to symptoms occurring almost always, often, sometimes, hardly ever, and never [24–26].

Average Prevertebral Soft Tissue Thickness

Lateral cervical spine radiography was performed on patients 2 days, 1 month, 3 months and 6 months after the surgery. The APSTT at C2–C7 were measured by three independent clinical practitioners on the lateral cervical spine radiographs taken from the front of the plate [27] (Fig. 2).

Data Analysis

Chi-squared test was used to compare the differences in the female-to-male ratio, single level cervical surgery ratio and incidence of dysphagia between groups A and B. Two-sample independent *t*-test was used to compare the difference in age, BMI, operation time, blood loss, anesthesia time, SWAL-QOL scores and APSTT between the groups. A *p*-value less than 0.05 (two-tailed) was considered statistically significant. All statistical analyses were performed on SPSS version 22.0 (IBM Corp, Armonk, NY, USA).

Results

Characteristics of the Study Groups

Table 1 shows the characteristics of the study groups. There were no significant differences in age, sex, BMI, single segment surgery rate, operation time, blood loss and anesthesia time between groups A and B ($p > 0.05$).

Incidence of Dysphagia

No patients reported dysphagia before surgery and at 6 months after surgery. Group A had a significantly lower incidence of dysphagia than group B at 2 days, 1 week and 1 month after surgery ($p < 0.05$). There were no significant differences in the incidence of dysphagia between groups A and B at 3 months after surgery ($p > 0.05$) (Table 2).

Swallowing Quality of Life Scores

No significant differences were found between groups A and B in terms of SWAL-QOL scores before surgery ($p > 0.05$). The SWAL-QOL scores of group A were significantly higher than those of group B at 2 days, 1 week, 1 month and 3 months after surgery ($p < 0.05$). However, as the follow-up time was extended beyond 3 months, the SWAL-QOL score in each group gradually returned to the preoperative levels, and there were no significant differences in SWAL-QOL score between groups A and B at 6 months after surgery ($p > 0.05$) (Table 3).

Average Prevertebral Soft Tissue Thickness

No significant differences in APSTT were found between groups A and B before surgery, and at 2 days,1 month, 3 months and 6 months after surgery ($p > 0.05$). Of note, we found that postoperative APSTT was larger than preoperative APSTT within each group, and the APSTT at 2 days after surgery was the largest for groups A and B. Nevertheless, the postoperative APSTT gradually returned to the preoperative levels as the follow-up time extended (Table 4).

Discussion

Anatomical Features of Longus Colli Muscle and Anterior Longitudinal Ligament

The LCM is situated on the anterior surface of the vertebral column, between the atlas and the third thoracic vertebra. It is covered by the pharynx and esophagus and is divided into the anterior medial and superior lateral portions [28]. The inferior medial portion arises from the front of the bodies of the first two or three thoracic vertebrae (T1–T3) and is inserted by the anterior tubercles of the transverse processes of the fifth to seventh cervical vertebrae (C5–C7)

Table 2. The incidence of dysphagia between groups A and B.

Follow-up	Group A (n = 35)	Group B (n = 56)	χ^2 value	*p*-value
Preoperation	0	0		
2-day postoperation	9	27	4.560	0.033
1-week postoperation	7	24	5.010	0.025
1-month postoperation	3	15	4.503	0.034
3-month postoperation	1	3	0.320	0.571
6-month postoperation	0	0		

Table 3. SWAL-QOL scores in groups A and B at different time points.

Follow-up	Group A (n = 35)	Group B (n = 56)	T value	*p*-value
Preoperation	63.00 ± 0.97	63.32 ± 1.11	1.406	0.163
2-day postoperation	47.80 ± 2.10	41.93 ± 2.84	10.536	0.000
1-week postoperation	49.51 ± 2.03	45.79 ± 3.39	5.867	0.000
1-month postoperation	53.77 ± 1.21	50.77 ± 2.56	6.493	0.000
3-month postoperation	61.37 ± 1.85	59.00 ± 2.07	5.533	0.000
6-month postoperation	63.60 ± 1.06	63.29 ± 0.89	1.521	0.132

SWAL-QOL, swallowing quality of life.

and the cervical vertebra body of the second to fourth cervical vertebrae (C2–C4). The superior lateral portion arises from the anterior tubercles of the transverse processes of the third, fourth, and fifth cervical vertebrae (C3–C5) and is inserted by a narrow tendon into the tubercle on the anterior arch of the atlas [29]. The ALL traverses all the vertebral bodies and intervertebral discs and runs down the anterior surface of the spine. It has three layers: (i) the superficial layer, which traverses C3–C4; (ii) the intermediate layer, which covers C2–C3; and (iii) the deep layer, which is situated between vertebrae [30]. The ALL helps provide stability to the spinal column, limits flexion and prevents overextension [31]. On the sagittal position, the LCM and ALL lie on top of the anterior cervical vertebra body, which is a soft tissue layer of about 3–4 mm in thickness. The LCM acts with the other cervical flexors to produce neck flexion and cervical rotation. The suture should not exceed 0.5 cm from the medial border of LCM because the medial border of LCM is located adjacent to the cervical sympathetic trunk, which can be injured during surgery, thereby causing Horner's syndrome [32]. During the follow-up period, cases of Horner's syndrome were not reported. Thus, this implies that the surgeon involved performed meticulous sutures of LCM and ALL in this study.

Clinical Significance of Reconstructions of Longus Colli Muscle and Anterior Longitudinal Ligament

After reconstructions of LCM and ALL, the implanted hardware was covered up by muscular tissues but did not appear directly posterior to the esophagus. The adhesion attaching the esophagus to the prevertebral plate was one of the main causes of dysphagia [33]. Using interverte-

bral fixation can reduce mechanical irritation of the esophagus, so the smoother and thinner posterior esophagus tissues can help reduce the occurrence of dysphagia [33]. Meanwhile, reconstructions of LCM and ALL can reduce the risk of esophageal fistula since this complication usually happens when the esophageal surface is too close to the rough surface of the implanted plates. Additionally, given that inadequate drainage may occur locally after surgery, we recommend that LCM and ALL stitches should not be made too tightly to the implanted plates in order to prevent hematoma formation, which was not reported in this study, so as to avoid obstruction to extracting blood from the cervical canal.

Incidence of Postoperative Dysphagia

Dysphagia refers to the difficulty swallowing solids or liquids materials, a lack of pharyngeal sensation, or other inadequacies of the swallowing mechanism [34]. It is known as one of the most common complications of ACS with a wide range of reported incidence from 1% to 79% [31–34]. The broad range of the incidence is attributed to the varying diagnostic criteria used in different studies. In the current study, we used the classic Bazaz dysphagia scale [22] to determine the incidence of postoperative dysphagia. Bazaz dysphagia scale was the first tool used to evaluate patients with cervical diseases [35]. Our results showed that the dysphagia incidence of LCM and ALL suture group (group A) was significantly lower than that of the non-suture group (group B) at 2 days, 1 week,1 month and 3 months after surgery.

Table 4. Average prevertebral soft tissue thickness (APSTT) in groups A and B at different time points.

Follow-up	Group A, mm (n = 35)	Group B, mm (n = 56)	T value	*p*-value
Preoperation	10.14 ± 1.51	9.90 ± 1.43	0.742	0.460
2-day postoperation	12.76 ± 1.94	12.89 ± 2.68	0.239	0.812
1-month postoperation	11.47 ± 2.53	11.19 ± 1.75	0.628	0.532
3-month postoperation	10.92 ± 1.85	10.68 ± 1.50	0.680	0.498
6-month postoperation	10.93 ± 1.72	10.35 ± 1.40	1.748	0.084

Dysphagia and Swallowing Quality of Life Scores

Our study found that the SWAL-QOL scores were reduced after ACS, and they were significantly higher in group A than in group B at 2 days, 1 week,1 month and 3 months after surgery. The SWAL-QOL was one of the tools designed to measure the degree of dysphagia for patients with head and neck cancer, esophageal diseases, or chronic neurological disorders [36]. This study also indirectly presented that the low SWAL-QOL scores coincided with the high incidence of postoperative dysphagia, which was evaluated by Bazaz dysphagia scale, indicating that dysphagia is caused by ACS.

Average Prevertebral Soft Tissue Thickness

Prevertebral soft tissue edema is one of the possible causes of dysphagia [37]. In order to assess the extent of soft tissue edema, the APSTT was measured from the lateral cervical spine radiographs taken from the front of the plate [38]. In this study, no statistically significant differences were found between groups A and B in terms of APSTT after surgery.

Conclusion

There are several limitations to this study. First, errors in APSTT measurements may occur because of partially overlapping areas between the prevertebral soft tissues and shoulders in X-rays images. However, all APSTT measurements taken in this study were of high accuracy because it was measured by an experienced clinical practitioner. The application of computed tomography (CT) or MRI should be given due consideration in APSTT measurement since it is costly, time-consuming and detrimental in terms of radiation exposure. However, the limitations concerning cost and convenience were addressed in this study since X-rays was applied in APSTT measurement.

Second, there is no unified, objective method for diagnosing dysphagia and identifying swallowing problems after ACS. The incidence and degree of dysphagia were mainly determined using self-evaluated questionnaires, which were set to survey this aspect based on patients' subjective experiences. This may add variability to the results since the patients with the same dysphagia severity may rate differently in the questionnaire.

Third, the duration and intensity of the retractor system used, as well as the impact of applying tracheal cannula, which are potential confounders, were not taken into account in the present study.

In conclusion, reconstructions of LCM and ALL after ACS can effectively improve the postoperative swallowing function in the early phase.

Availability of Data and Materials

The data used to support the findings of this study are available from the corresponding author upon request.

Author Contributions

CLS, PG, JCC, KXL, ZGZ, EXT and BZ conceived and coordinated the study, designed, performed, and analyzed the experiments, and wrote the paper. CLS, PG and JCC designed the study, carried out the data collection, data analysis, and revised the paper. KXL carried out the data analysis and revised the paper. ZGZ and EXT carried out the data analysis and revised the paper. BZ carried out the data analysis and revised the paper. All authors reviewed the results and approved the final version of the manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was approved by the Medical Ethics Committee of the First Affiliated Hospital of Anhui Medical University (Quik-PJ 2022-06-63). This study was performed in accordance with the Declaration of Helsinki. Informed consent was obtained from all patients.

Acknowledgment

Not applicable.

Funding

This work is supported by Anhui Provincial Science and Technology Foundation, China (no. 2022e07020046) and Research Project of Anhui Educational Committee (no. 2022AH051152).

Conflict of Interest

The authors declare no conflict of interest.

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