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Skip corpectomy and fusion (SCF) versus anterior controllable antedisplacement and fusion (ACAF): which is better for patients with multilevel cervical OPLL?

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Abstract

Background The aim of this study was to compare the clinical efficacy and radiological outcomes of skip corpectomy and fusion (SCF) with anterior controllable antedisplacement and fusion (ACAF) for treating multilevel ossification of the posterior longitudinal ligament (OPLL).

Methods 62 patients with multilevel OPLL who had undergone SCF or ACAF were analyzed retrospectively. Types of OPLL, occupying ratio (OR), Japanese Orthopaedic Association (JOA) score, Recovery Rate (RR), Neck Disability Index (NDI) score, Cobb's angles of C2–C7, operation time, blood loss, hospital stay, ratings for fusion assessment and complications were recorded and assessed.

Results Postoperative C2–C7 Cobb's angle (11.1 ± 3.2° vs. 13.7 ± 2.5°; $P < 0.05$), NDI scores at final follow-up (14.3 ± 1.6 vs. 13.3 ± 1.3; $P < 0.05$), and rate of cerebral fluid (CSF) leakage (5, 16.7% vs. 0,0%; $P < 0.05$) were significantly better in the ACAF group. At 6 months, bone graft fusion rate was significantly greater in the ACAF group (24.75% vs. 15.50%; $P < 0.05$).

Conclusions Surgical treatment of multilevel OPLL by SCF or ACAF showed no significant differences in clinical outcomes, with the exception of better NDI scores at final follow-up in ACAF. In addition, ACAF is better than SCF in terms of early bone graft fusion rate, lordotic curvature improvement, risk of CSF leakage.

Keywords Skip corpectomy and fusion (SCF) · Anterior controllable antedisplacement fusion (ACAF) · Ossification of the posterior longitudinal ligament (OPLL) · Fusion rate · Complication

Introduction

Surgical treatment of cervical spondylosis caused by multilevel ossification of the posterior longitudinal ligament (OPLL) included anterior and posterior approaches [1–5]. However, when three or more levels were involved in anterior approach, failure rates and complications significantly increased [6]. Compared with anterior approach, the posterior approach, including laminectomy and laminoplasty, is safer for not directly resecting the ventral OPLL [7, 8]. However, the clinical outcome of posterior approach was less satisfactory than anterior approach [9].

The skip corpectomy and fusion (SCF), reported by Ashkenazi et al. [10], was used to obtain the optimum decompression and fixation in patients with multilevel CSM and OPLL [11–13]. On the other side, in our previous study, we proposed a novel surgical technique, anterior controllable antedisplacement and fusion (ACAF), which also achieved

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satisfactory outcomes [14]. However, the efficacy of the two anterior decompression techniques for multilevel OPLL has not been compared.

Accordingly, the current study was designed to compare the use of SCF surgery with the use of ACAF surgery for the treatment of OPLL involving three or more levels and to compare perioperative parameters, incidence of complications, radiologic and clinical outcomes of the two techniques.

Materials and methods

Patient population

This was a retrospective clinical study. Between January 2016 and May 2017, a total of 78 consecutive patients underwent SCF or ACAF for multilevel OPLL by the same surgical team. All patients underwent X-ray, computed tomography (CT) and magnetic resonance imaging (MRI) to compare radiologic and clinical outcomes of these two surgical options for the treatment of multilevel OPLL.

Inclusion criteria were (1) symptoms of cervical myelopathy; (2) images showing OPLL involving three or more levels; (3) complete medical records, related radiographic data with 12 months or longer follow-up. Exclusion criteria were (1) history of cervical injury; (2) previous cervical surgery; (3) myelopathy caused by other diseases such as cerebral palsy or tumors. Nine patients were excluded for incomplete follow-up. Two patients were excluded for history of cervical injury. Four patients were excluded for previous cervical surgery. One patient was excluded for spinal tumor. Ultimately, 62 patients (29 males and 33 females) were included in this study. The surgeons fully communicated with the patients before surgery, so that all patients could understand the process, advantages and disadvantages of the two surgical methods and finally made the surgical choice. In addition, we were more likely to choose ACAF surgery for some patients with large OPLL behind the middle vertebral body which was difficult to be resected by SCF surgery. All patients signed informed consent. According to the surgical procedures, these patients were divided into two groups, SCF group and ACAF group.

Surgical technique

For both surgical techniques, patients were placed in a supine position with mild extension of the neck. Endotracheal intubation was performed via laryngoscope after receiving general anesthesia. The following surgical steps used C3–C7 as examples of three-level SCF and ACAF.

In the SCF group, after confirmation and exposure of the C3–C7 vertebras, C4 and C6 vertebras were partially removed using an appropriate rongeur and adjacent discectomy was performed. The residual vertebras and OPLL behind them were removed using high-speed drill and microdissector. The posterior vertebral margin was slightly cut to expand the surgical field of view for undercutting decompression of OPLL at C5 and avoid secondary compression after expansion of the dural sac. Then anterior fusion was performed with the allogeneic-bone-packed titanium mesh. An appropriately sized titanium plate was then firmly affixed to the C3 and C7 vertebras with screws. The screws of C5 vertebra was tightened at last [13] (Figs. 1, 2).

In the ACAF group, the anterior surface of C3–C7 vertebras was exposed through a right-sided or left-sided approach. Routine discectomies were carried out in the C3–C7 vertebras. Then the anterior part of C4–C6 vertebras was resected according to the thickness of the OPLL at the same levels. Allogeneic-bone-packed intervertebral cages were then inserted at involved levels. Then the prebent appropriately sized titanium plate and screws were temporarily installed. Bilateral troughs at C4–C6 vertebras were created on the basis of uncinate process. Finally, the vertebrae–OPLL complex (VOC) was hoisted via gradually tightening the screws [15] (Figs. 3, 4).

Clinical evaluation

Clinical assessment was performed by Japanese Orthopaedic Association (JOA) scores, Neck Disability Index (NDI) scores and recovery rate (RR); RR = (postoperative JOA scores − preoperative JOA scores/17 − preoperative JOA scores)/100%. Surgical outcomes were classified into four grades according to RR: (1) excellent ($RR \geq 75\%$), (2) good ($75\% > RR \geq 50\%$), (3) fair ($50\% > RR \geq 25\%$), and (4) poor ($RR < 25\%$) [14].

Radiologic evaluation and postoperative care

The radiologic outcomes were assessed using preoperative and postoperative plain radiographs, computed tomography (CT) scans, and magnetic resonance images (MRI). The parameters described as follows: (1) cervical lordosis (CL) was measured as the Cobb's angles for C2–C7 segments between the inferior border of C2 and C7 vertebras using plain radiographs. (2) The occupying ratio (OR) was measured on the axial CT scans. In the narrowest plane of spinal canal, OR = (thickness of OPLL/spinal canal anteroposterior diameter) × 100% [15]. (3) The fusion was classified into five grades based on plain radiographs according to the criteria proposed by Eck et al. [16] as follows. Grade I (definite): obvious trabeculations apparently crossing vertebral end plates; Grade II (probable): intact graft and no lucencies but without full remodeling and incorporation; Grade III (probably not): graft intact but with definite lucency apparent at

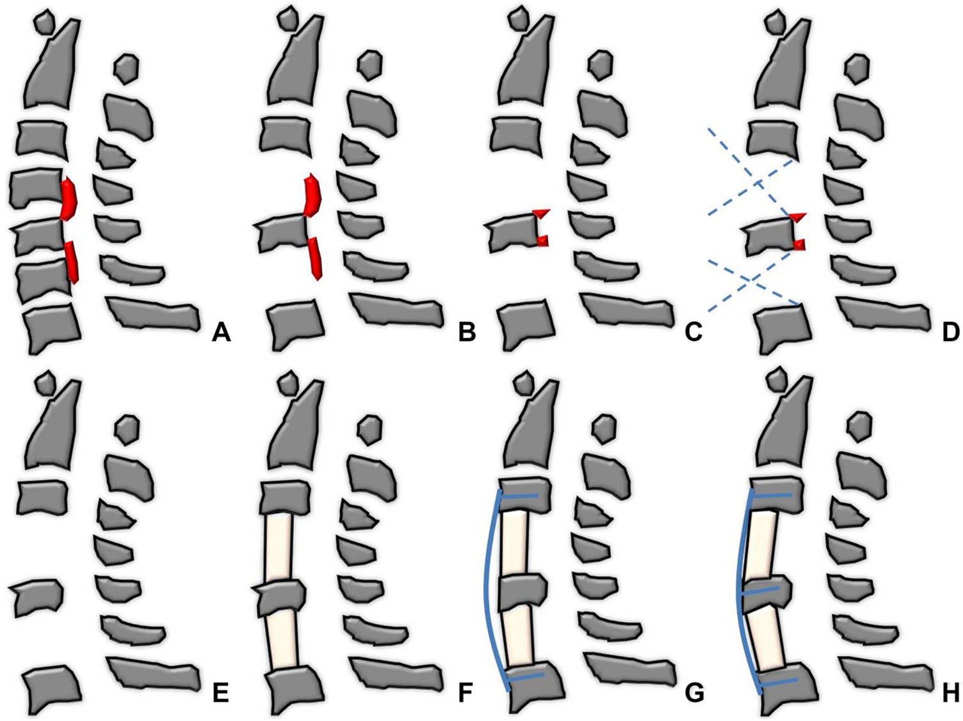

Fig. 1 Schematic diagram of surgical procedures of skip corpectomy and fusion (SCF) surgery. **a** Preoperative illustration of a case suitable for SCF surgery, showing OPLL at the C3–C6 levels. **b** C4 and C6 vertebras corpectomy and adjacent discectomy were performed. **c** OPLL behind C4 and C6 vertebras was completely removed. **d** The posterior vertebra margin was slightly cut. **e** Undercutting decompression of OPLL at C5 was performed. **e** The allogeneic-bone-packed titanium mesh was inserted. **g** The prebent anterior cervical plate was placed at C3–C7 levels and screws were installed at C4 and C6. **h** Finally, fix screws at C5 and gradually tighten the screws

the top or bottom of the graft; Grade IV (no): resorption of bone graft; Grade V: could not be assessed. All the radiologic outcomes were reviewed by two senior spine surgeons.

Postoperatively, all the patients were instructed to wear skull–neck–thorax braces for 3 months and then wear neck collars for protection before their fusions reached Grade I (definite).

Statistical analyses

SPSS version 19.0 software (SPSS Inc., Chicago, IL, USA) was used for the analysis. The results were expressed as mean ± standard deviation. Paired-sample *T* tests were used to compare the preoperative and postoperative parameters. Comparisons of quantitative data in the two groups were made using independent-sample *T* tests. Pearson's Chi-square tests were applied for comparisons of incidence of postoperative complications. Values of $p < 0.05$ were considered statistically significant.

Results

Clinicopathologic characteristics

As shown in Table 1, no significant differences between groups were found in sex, age, duration of symptom, follow-up and OR ($P > 0.05$). However, the ratio of continuous types of OPLL in ACAF group (928.1%) was significantly higher than that in SCF group (0.0%) ($P < 0.05$).

Clinical parameters

As shown in Table 2, the JOA scores increased sharply at final follow-up in both SCF and ACAF groups. Mean JOA scores for the SCF group increased from 8.2 ± 0.7 preoperatively to 13.8 ± 1.4 at final follow-up, with a mean RR of 63.5% ± 14.8%. Mean JOA scores for the ACAF group improved from 8.0 ± 1.1 preoperatively to 13.6 ± 1.3 at final follow-up, with a mean RR of 61.3% ± 15.7%. Mean JOA scores at last follow-up showed no significant difference between the two groups ($P > 0.05$). There were corresponding decreases in NDI scores at final follow-up in the two groups. Mean NDI scores for the SCF group decreased from 25.1 ± 1.6 preoperatively to 14.3 ± 1.6 at final follow-up. Mean NDI scores for the ACAF group improved from 25.3 ± 1.7 preoperatively to 13.3 ± 1.3 at final follow-up. Mean NDI scores at last follow-up were significantly different between the two groups ($P < 0.05$). No significant differences between groups were found in operation time, blood loss and hospital stay ($P > 0.05$).

Radiologic results

Postoperative Cobb angle of the C2–C7 segments increased significantly in both groups (Table 2). The Cobb angle increased from 6.4 ± 3.0 to 11.1 ± 3.2 in the SCF group, and

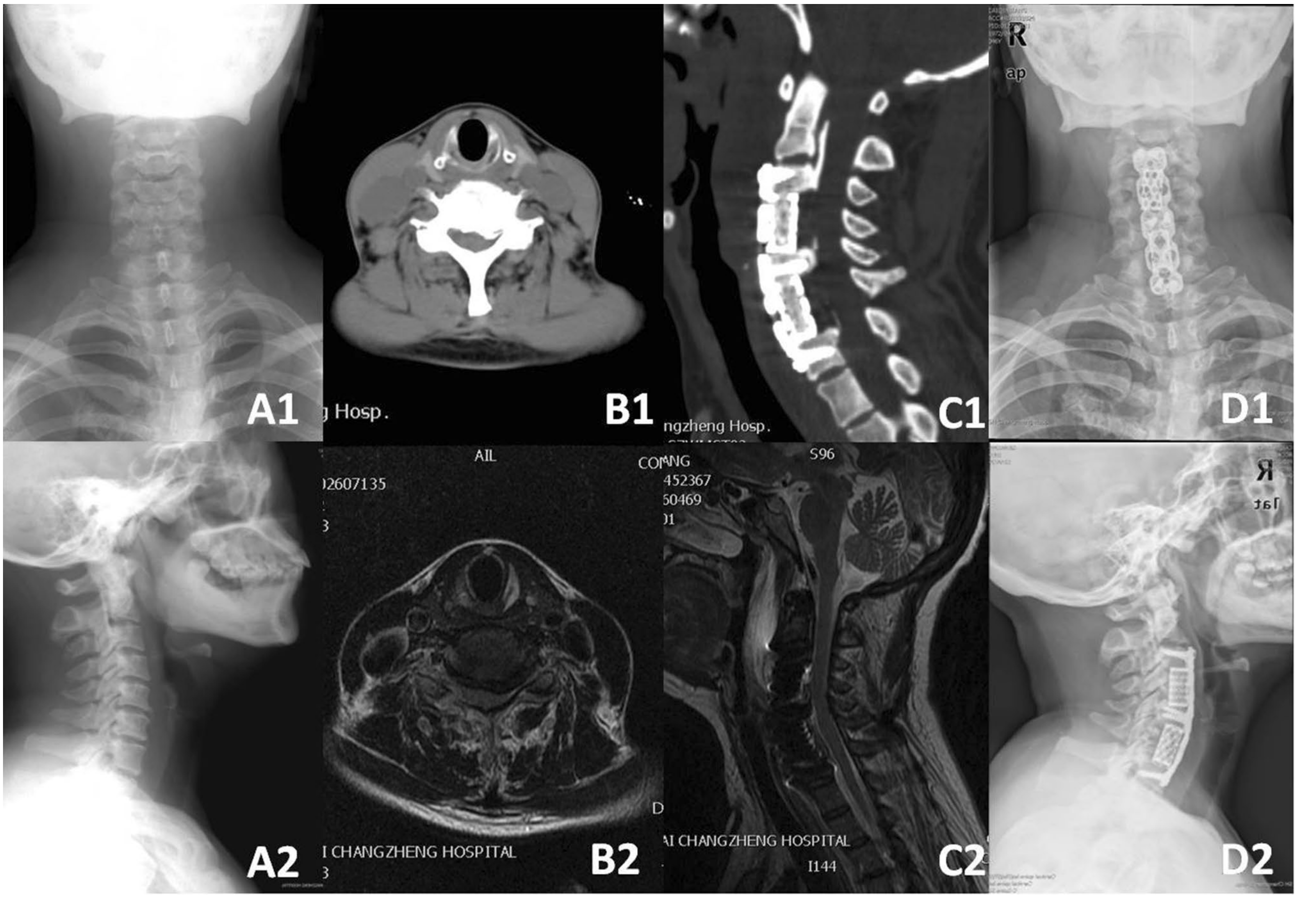

Fig. 2 A 56-year-old male patient in SCF group presented with numbness in both hands accompanied by weakness in all four extremities for 1 year. A1: preoperative anterior–posterior tomography. A2: preoperative lateral tomography. B1: preoperative CT demonstrated the OPLL at C4. B2: preoperative T2-weighted MRI demonstrated the compression at C4. C1: postoperative CT sagittal reconstruction showed the decompression. C2: postoperative T2-weighted MRI showed the decompression. D1: postoperative anterior–posterior tomography. D2: postoperative lateral tomography. *SCF* skip corpectomy and fusion, *OPLL* ossification of the posterior longitudinal ligament, *CT* computed tomography, *MRI* magnetic resonance images

from 6.8 ± 2.4 to 13.7 ± 2.5 in the ACAF group. No significant difference was found in preoperative C2–C7 Cobb angle between the two groups ($P > 0.05$). However, postoperative Cobb angles were found significantly higher in the ACAF group than in the SCF group ($P < 0.05$) (Table 2).

In ratings for fusion assessment 6 months after surgery, the ratio of Grade I (definite) (24.75% vs. 15.50%; $P < 0.05$) was significantly greater in the ACAF group. No significant differences of fusion rate between groups were found in other postoperative times (Fig. 5).

Complications

As shown in Table 3, postoperative surgery-related complications were more common in the SCF group (33.2%) than in the ACAF group (6.2%) ($P < 0.05$). The ratio of cerebral fluid (CSF) leakage (5.16.7% vs. 0.0%; $P < 0.05$) was significantly higher in SCF group. In all patients, C5 nerve root palsy, hoarseness, epidural hematoma, dysphagia, and axial neck pain improved after conservative treatments for 2 weeks and had made complete recovery at the 12-week follow-up. Besides, complications associated with instrumentation and graft were found in one patient in the SCF group (3.3%) and 0 patient in the ACAF group ($P > 0.05$). In the SCF group, we found one patient with graft dislodgement (3.3%). However, the patient did not show significant clinical symptoms and had not received revision surgery till now.

Discussion

Surgical approach for multilevel OPLL

Anterior approach for 1–2 levels of OPLL has achieved satisfactory outcomes. However, many authors reported a high

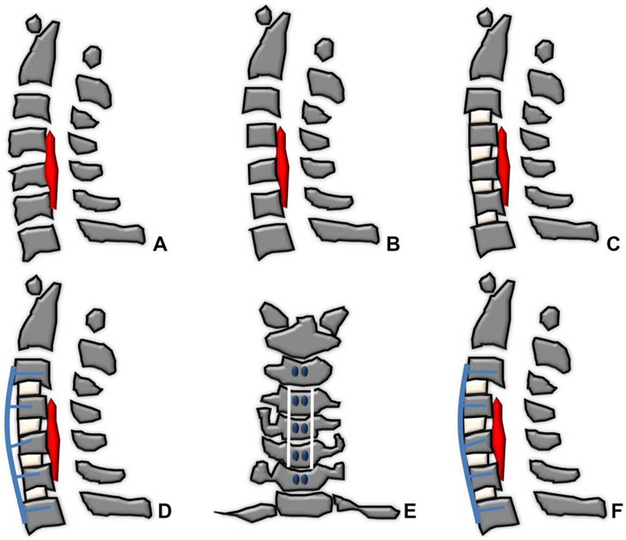

Fig. 3 Schematic diagram of surgical procedures of anterior controllable antedisplacement and fusion (ACAF) surgery. **a** Multilevel OPLL involving C4–C6 levels; **b** routine discectomies were carried out in the C3–C7 levels. Then resect the anterior part of C4–C6 vertebras according to the thickness of the correlated OPLL. **c** Allogeneic-bone-packed intervertebral cages were then inserted at C3–C7 levels. **d** The prebent anterior cervical plate and screws were temporarily installed at C3–C7 levels. **e** Bilateral troughs about 2 mm were created at C4-C6 vertebras on the base of uncinate process. **f** The vertebrae–OPLL complex (VOC) was hoisted via gradually tightening the screws at C4–C6 levels

failure rate of long segment anterior cervical plate fixation after a multilevel corpectomy more than three levels [7, 17, 18]. Posterior approach for OPLL may be another option. However, some scholars believed that when the patient's cervical curvature was poor or the compression rate was greater than 60%, the posterior approach was not effective [9, 19].

Proposal of SCF and ACAF surgeries

The SCF, two one-level corpectomies leaving the middle vertebra, was an anterior technique widely used for multilevel cervical myelopathy and OPLL recent years [12]. Clinical reports [11, 13] showed that the SCF surgery achieved more stability than three-level corpectomy especially during lateral bending. The biomechanical study, comparing SCF surgery with multilevel corpectomy, reported that SCF surgery significantly reduced peak screw pull-out force during axial rotation [20].

There are two main purposes for surgical treatment of OPLL: one is effective and safe decompression of the spinal cord; the other is immediate and long-term stability of the cervical spine. Based on clinical practice and research, we proposed ACAF surgery which was especially satisfactory for multilevel OPLL [15]. The ACAF surgery is unlikely to damage the cervical spinal cord as well as nerve roots and arteries using anatomical markers during surgery [21]. Moreover, the ACAF surgery is safe for not cutting the OPLL [14]. ACAF surgery can also reserve more vertebrae and provide additional screw purchase, which may obtain effective stability of the spinal column.

Cervical curvature and NDI scores

Both SCF and ACAF surgery can restore cervical disc height and lordosis. In this study, cervical lordosis of fusion segments was significantly increased in both groups, but the increase was greater in the ACAF group than in the SCF group ($P < 0.05$). In the ACAF group, cervical lordosis can be achieved and maintained easily than in SCF group, which may be due to the multiple distraction points of distraction and fixation in addition to the graft and interbody space [22]. The ACAF group can restore cervical lordosis by pulling the involved three or more vertebras; but SCF surgery using corpectomy grafts may only pull the remaining one vertebra to restore the curvature. Better cervical lordosis improvement compared to the SCF group may also contribute to more satisfactory NDI scores at final follow-up in the ACAF group.

Fusion rate

All the types of anterior approach were linked to a loss of stability in the cervical spine, which made reconstruction and fusion necessary. An increased rate of complication and fusion failure was observed that was proportional to the length of the anterior construct [23]. The lower fusion rates have been previously reported to associate with an increased number of grafts and interfaces which may increase stresses and resultant motion at the graft sites and rate of arthrodesis with strut grafting after multilevel decompression. Postoperative bone graft fusion was an important indicator of successful spine surgery and a major indicator of clinical efficacy. However, bone fusion as a dynamic process was closely related to time. Therefore, to more accurately understand the bone fusion, plain radiographs of all the patients were taken at 3, 6, and 12 months postoperatively. In this study, we found that the fusion of the two groups was equivalent at 3 months and 12 months after surgery. However, the number of Grade I in the ACAF group was significantly higher than that in the SCF group at 6 months after surgery, suggesting that the early fusion rate of ACAF surgery was higher than that of the SCF group ($P < 0.05$). The SCF and ACAF groups received 96.7% and 100% of the Graded I (definite) fusion, respectively, at 12 months after surgery, which were higher than the previous studies of standard three-level corpectomy [24, 25].

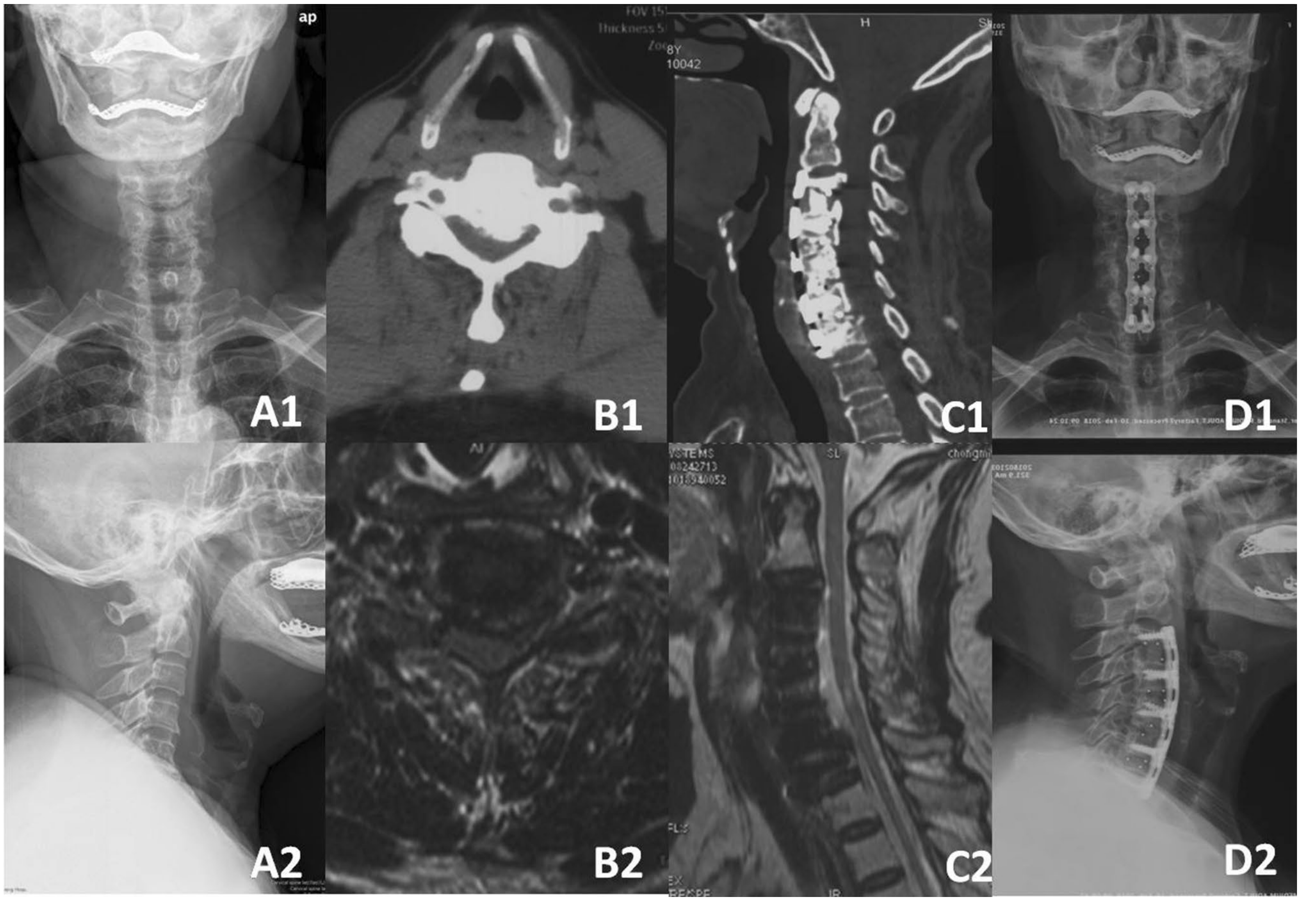

Fig. 4 A 61-year-old female patient in ACAF group presented with numbness and weakness in all four extremities for 2 years. A1: preoperative anterior–posterior tomography. A2: preoperative lateral tomography. B1: preoperative CT demonstrated the OPLL at C4. B2: preoperative T2-weighted MRI demonstrated the compression at C4. C1: postoperative CT sagittal reconstruction demonstrated satisfactory antedisplacement of VOC from C4 to C6. C2: postoperative T2-weighted MRI showed the decompression of spine cord. D1: postoperative anterior–posterior tomography. D2: postoperative lateral tomography. *ACAF* anterior cervical corpectomy and fusion, *OPLL* ossification of the posterior longitudinal ligament, *CT* computed tomography, *MRI* magnetic resonance images, *VOC* vertebrae–OPLL complex

Table 1 Patient demographic data

Variable	SCF group ($n=30$)	ACAF group ($n=32$)	Total ($n=62$)	*P* value
Sex (male, female)	14, 16	15, 17	29, 33	0.987
Age, years (range)	53.3 ± 7.0 (36–70)	49.8 ± 10.2 (35–72)	51.5 ± 8.9 (35–72)	0.123
Symptom duration, months (range)	30.3 ± 18.3 (2–76)	27.0 ± 14.4 (2–80)	28.6 ± 16.4 (2–80)	0.289
Follow-up period, months (range)	18.6 ± 4.7 (13–27)	19.8 ± 3.4 (12–24)	19.2 ± 4.1 (12–27)	0.232
Types of OPLL continuous (%)	0 (0)	9 (28.1)	9 (14.5)	0.002*
Segmental (%)	8 (26.7)	6 (18.8)	14 (22.6)	0.456
Mixed (%)	12 (40)	10 (31.3)	22 (35.5)	0.472
Localized (%)	10 (33.3)	7 (21.8)	17 (27.4)	0.312

Values are expressed as the mean ± standard error, with the range in parentheses

SCF skip corpectomy and fusion, *ACAF* anterior controllable antedisplacement and fusion, *OPLL* ossification of the posterior longitudinal ligament

*$p < 0.05$

Table 2 Patient clinical and radiologic outcomes

Variable	SCF group ($n=30$)	ACAF group ($n=32$)	P value
Preoperative JOA scores	8.2 ± 0.7	8.0 ± 1.1	0.405
JOA scores at final follow-up	13.8 ± 1.4	13.6 ± 1.3	0.550
Preoperative NDI scores	25.1 ± 1.6	25.3 ± 1.7	0.732
NDI scores at final follow-up	14.3 ± 1.6	13.3 ± 1.3	0.008*
RR of the JOA (%)	63.5 ± 14.8	61.3 ± 15.7	0.562
RR (excellent/good/fair/poor)	5/19/6/0	6/16/10/0	0.526
Preoperative C2–C7 Cobb angle (°)	6.4 ± 3.0	6.8 ± 2.4	0.521
Postoperative C2–C7 Cobb angle (°)	11.1 ± 3.2	13.7 ± 2.5	0.001*
Operation time (min)	154.6 ± 17.1	153.8 ± 18.9	0.864
Blood loss (mL)	264.0 ± 53.2	245.3 ± 36.3	0.109
Hospital stay (days)	9.0 ± 1.2	8.4 ± 1.3	0.078

Values are expressed as the mean ± standard error, with the range in parentheses

SCF skip corpectomy and fusion, *ACAF* anterior controllable antedisplacement and fusion, *JOA* Japanese Orthopaedic Association, *NDI* neck disability index, *RR* recovery rate

*$p < 0.05$

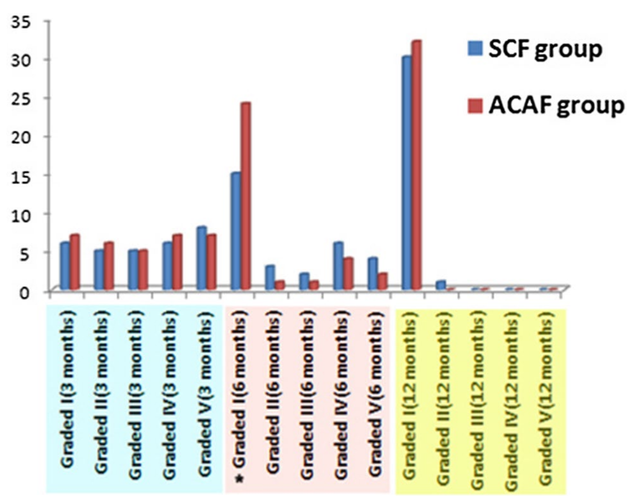

Fig. 5 Ratings for fusion assessment. *SCF* skip corpectomy and fusion, *ACAF* anterior controllable antedisplacement and fusion; Grade I (definite): obvious trabeculations apparent crossing vertebral end plates; Grade II (probable): intact graft and no lucencies but without full remodeling and incorporation; Grade III (probably not): graft intact but with definite lucency apparent at the top or bottom of the graft; Grade IV (no): resorption of bone graft; Grade V: could not be assessed. *$p < 0.05$

Table 3 Patient complications

	SCF group ($n=30$)	ACAF group ($n=32$)	P value
Surgery-related complications			
Infection (%)	0 (0)	0 (0)	1.000
C5 palsy (%)	1 (3.3)	1 (3.1)	0.963
Cerebral fluid leakage (%)	5 (16.7)	0 (0)	0.022*
Epidural hematoma (%)	1(3.3)	0 (0)	0.484
Hoarseness (%)	1 (3.3)	1 (3.1)	0.963
Axial neck pain (%)	1 (3.3)	0 (%)	0.484
Dysphagia (%)	1 (3.3)	0 (%)	0.484
Total (%)	10 (33.2)	2 (6.2)	0.010*
Instrumentation and graft-related complications			
Hardware breakage (%)	0	0	1.000
Graft dislodgement (%)	1 (3.3)	0 (%)	0.484
Subsidence (%)	0 (%)	0 (%)	1.000
Total (%)	1 (3.3)	0 (%)	0.484

Values are expressed as the mean ± standard error, with the range in parentheses

SCF skip corpectomy and fusion, *ACAF* anterior controllable antedisplacement and fusion

*$p < 0.05$

Efficacy and complications

In this study, both the SCF and ACAF groups demonstrated a significant increase in postoperative JOA scores and RR showed no significant difference between two groups (63.5 ± 14.8 vs. 61.3 ± 15.7; $P > 0.05$). However, patients undergoing SCF surgery had a high risk of leakage of CSF compared to ACAF group. It might be because some patients have ossification of the dura mater, and SCF surgery required excision of the OPLL, which might cause dural rupture and CSF leakage, especially in the remaining vertebral level. Due to the preservation of the vertebra, the surgeons had a poor visual field for surgical removal of the OPLL, and was more prone to intraoperative dural injury and CSF leakage [12].

Surgical application range

It is also worth noting that the thickness and position of the OPLL have a great influence on the SCF surgery. The SCF technique preserved one vertebra and undercutting decompression of the vertebra was required to resect the OPLL. If the OPLL was thick or continuous, the undercutting decompression operation would be difficult and unlikely to achieve completely decompression, and even more complications occurred. Some scholars also pointed out that patients with continuous OPLL should not choose SCF surgery [12]. The ACAF procedure does not directly resect the OPLL, so there was no need to consider this factor. At this point, the ACAF surgery had a wider range of application than SCF surgery.

Limitation

Limitations to the present study include the retrospective design, relatively short follow-up time, small sample size, and compression differences between the two groups which could theoretically bias the results. Therefore, randomized controlled trials with larger sample sizes and longer follow-up times are needed to further investigate the differences between these two techniques.

Conclusion

Both surgical methods had achieved good clinical outcomes, and the postoperative cervical curvature and the fusion rate were satisfactory. However, ACAF surgery was associated with significantly higher early bone graft fusion rate, greater lordotic curve change, more satisfactory NDI scores at final follow-up and lower risk of CSF leakage. Therefore, we recommend when treating multilevel OPLL, SCF and ACAF surgery may be substitutes for standard three-level corpectomy. In addition, when the OPLL of patients is continuous, or large OPLL is behind the middle vertebral body, SCF surgery will be difficult to completely remove the OPLL, and then ACAF surgery may be a better alternative.

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Compliance with ethical standards

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

Ethical approval This article was approved by Medical Ethics Committee of Shanghai Changzheng Hospital. Approval file number: 2017SL040.

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