



CLINICAL ARTICLE

Comparative Study between Caspar Cervical Retractor System and Traditional S Retractor in Application on Anterior Cervical Decompression and Fixation

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Objective: Although Caspar cervical retractor system (CCRS) is commonly utilized in anterior cervical decompression and fixation (ACDF), most urban hospitals still use both traditional S retractor and CCRS in conventional anterior cervical surgeries. Related data to evaluate the effect are required to be reported. The aim of this study is to compare the efficacy between using the traditional cervical S retractor and CCRS in anterior cervical decompression and fixation ACDF.

Methods: The retrospective study that total 360 patients received ACDF using different retractors (traditional S retractor or CCRS) were enrolled in this study from January 2010 to January 2020. Width change rate of cervical prevertebral soft tissue, throat symptoms, and subjective experiences of the operating surgeons were evaluated by t-test or analysis of variance (ANOVA) respectively.

Results: The width change rate of prevertebral soft tissue was significantly higher in the S retractor group than that of the CCRS group both in single segment group (40.9% vs 20.8%, $P < 0.05$) and double segments group (45.8% vs 25.2%; $p < 0.05$). In the three segments group, the width change rate of prevertebral soft tissue was higher in the S retractor group than that of the CCRS group, but with no statistical significance (27.3% vs 23.6%; $P > 0.05$). The incidence rates of dysphagia, dyspnea, and throat discomfort in the traditional S retractor group were significantly higher compared to the CCRS group ($P < 0.05$), while satisfactory rate of surgeon was higher in the CCRS group ($P < 0.05$). However, there was no correlation between anterior soft tissue rate and operative time ($P > 0.05$), as well as the width change rate of anterior soft tissue and the DNRS score ($P > 0.05$).

Conclusion: CCRS was superior compared to the traditional S retractor in reducing the postoperative complications and the postoperative fatigue of surgeon. Meanwhile, the width change rate of prevertebral soft tissue was not related to operative time and DNRS score.

Key words: Anterior cervical vertebra; Minimally invasive retractor; Soft tissue swelling; Throat symptoms

Introduction

Anterior cervical surgeries including anterior cervical discectomy, anterior cervical decompression and fixation

(ACDF), subtotal cervical corpectomy, anterior cervical spine fixation (ACSF), and artificial cervical disc replacement (ACDR) are the common strategies for the treatment of

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cervical degenerative diseases.¹⁻³ During the exposure and operation of anterior cervical surgeries, the conventional approach is that the traditional S retractor is utilized by two assistants to pull the visceral sheath and vascular sheath respectively. In the engagement of operation, usually surgeons should modulate positions for several times due to long-term period overburdening the assistants by manual stretching and visual field occlusion. Moreover, surrounding soft tissue often protrudes into the operation field originated from inappropriate traction or unsuitable force implementation, eventually resulting in inadvertent injury and postoperative soft tissue swelling, which may trigger various postoperative complications such as esophageal fistula, dysphagia, dyspnea, and airway obstruction.^{4,5}

With the aim of improving the safety of the operation, as well as diminishing postoperative complications and the fatigue of surgeons, the Caspar cervical retractor system (CCRS), a side loading device which can block the soft tissue around the operation field through a small incision and clearly expose the operation field, is used in ACDF to reduce the fatigue of surgeons during the operation. Though CCRS is commonly utilized in ACDF, most urban hospitals still use both traditional S retractor and CCRS in conventional anterior cervical surgeries. Related data to evaluate the effect is needed.

We herein retrospectively enrolled the clinical and imaging data of 210 patients with CCRS and 150 patients with traditional S retractor for ACDF. By comparing the incidence of prevertebral soft tissue swelling, risk factors of throat symptoms after anterior cervical surgery, and subjective experiences of the operating surgeons with traditional S retractor and CCRS respectively, we hope to elucidate: (i) the different efficacy in two retractors; and (ii) whether CCRS is superior to traditional S retractor.

Materials and Methods

Clinical Data

This study was approved by the Institutional Review Board (IRB) of Qilu Hospital of Shandong University (KYL-2021 (KS)-606). A total of 360 patients (182 males and 178 females) with age range of 28–80 years who had ACDF surgery were enrolled from January 2010 to January 2020. Inclusion criteria: (i) patients who had ACDF in our hospital

and S retractor or CCRS was used during the operation; (ii) complete follow-up process was accepted after operation; and (iii) complete imaging examination before and after operation. Exclusion criteria: (i) history of cervical tumors; (ii) previous medical history of cervical surgery; and (iii) radiographs were too unclear to be measured.

A total of 150 cases were used by traditional S retractor (108 single segment cases, 36 double segments cases, and 6 three segments cases), while 210 cases were performed with CCRS (168 single segment cases, 30 double segments cases, and 12 three segments cases) (Fig. 1). Age of average was presented as 52.3 ± 5.6 years old in the traditional S retractor group and 50.7 ± 3.9 years old in CCRS, and patients were also divided into three groups according to 20-year old interval in this study. Basic diseases (hypertension, diabetes mellitus and cardiopathy) and clinical diagnosis as well as segments in two groups were also counted in. Post-operative parameters containing operative time, intraoperative blood loss and surgical incision length were collected. Detailed information about these patients were presented in Table 1.

Prevertebral Soft Tissue Width Measurement

The preoperative and third-day postoperative lateral X-ray radiographs of cervical spine were collected and the width of soft tissue at the pertinent surgical segment was measured by PACS imaging system as previously reported.^{6,7} Briefly, the distance from the midpoint of the anterior edge of each vertebral body to the posterior edge of the airway shadow was measured in terms of the vertebral hyperplasia here was mild, and it was generally not involved when the vertebral bone needed to be abraded during the operation, and consistency was guaranteed. Meanwhile, the starting point for measurement was selected at the presumed non-proliferative vertebral margin when osteophyte formation presented. The ratio of the width of the prevertebral soft tissue of the vertebrae fixed postoperatively and preoperatively to the width of the corresponding vertebrae was calculated, and the difference was calculated as the ratio of the change in the width of the prevertebral soft tissue of the related vertebrae. The mean of multiple rates of change was calculated to represent the degree of prevertebral soft tissue swelling (Fig. 2).

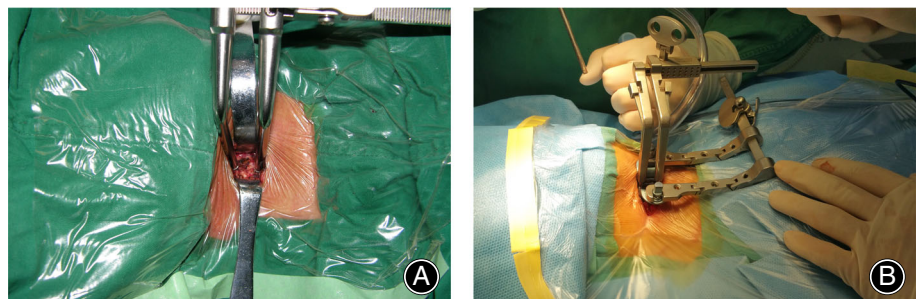


Fig. 1 The application of two retractors in operation. (A) Traditional S retractor; (B) CCRS

TABLE 1 The comparison between the traditional S retractor group and CCRS group

	Traditional S retractor	CCRS
Total	150	210
Gender		
Male	80	102
Female	70	108
Age (years)	52.3 ± 5.6	50.7 ± 3.9
20–40	23	32
40–60	83	106
60–80	44	72
Basic diseases		
Hypertension	28	35
Diabetes mellitus	11	18
Cardiopathy	3	1
Clinical diagnosis		
Single CDH	92	134
CDH combined with osteophyte	40	48
OPLL	18	28
Segment (s)		
Single	108	168
Double	36	30
Three	6	12
Operative time (min)		
Single	128 ± 8.4	120 ± 9.5
Double	182 ± 7.5	166 ± 8.5
Three	234 ± 10.3	216 ± 6.3
Intraoperative blood loss (ml)	91.67 ± 22.48	99.29 ± 28.08
Surgical incision length (cm)	6.05 ± 1.12	5.96 ± 1.06
Postoperative complications		
Dyspnea	6	4
Hoarseness	1	0
Hematoma	1	0
Dysphagia	10	7
Satisfaction rate (%)	85.3 (128/150)	95.7 (201/210)*
VAS score	3.2 ± 0.9	1.3 ± 0.4*

Abbreviations: CDH, cervical disc herniation; PLL, posterior longitudinal ligament.; * $P < 0.05$.

Comparison of Postoperative Complications

The incidence of dyspnea and dysphagia between the two groups were compared respectively. We conducted the dyspnea scale (Dysphagia Numerical Rating Scale, DNRS) with the range of 0–10 in accordance with previous study.⁸ A score of zero represents no dysphagia, a score range of 1–3 represents mild dysphagia, a score range of 4–6 represents moderate dysphagia, and a score range of 7–10 represents severe dysphagia. Whereas the patients were considered to dyspnea when they developed significant subjective symptoms postoperatively that with the requirement of continuous oxygen inhalation, shaking of the head of the bed, or other dispositions.

Intraoperative Subjective Experience Evaluation

The subjective experiences of the operating surgeons were compared based on satisfaction with the application of the traditional S retractor and the CCRS in operation. In

addition, postoperative visual analogue scale (VAS) scores with the range of 0–10 were recorded for discomfort in both arms of the first assistant.⁹

Statistical Analysis

All statistical analysis was performed using the software SPSS 18.0 (Chicago, IL, USA). Data were presented as mean ± standard deviation (SD). The prevertebral soft tissue width change rate and complication rate of different surgical segments between the two groups were analyzed using χ^2 test. The comparison of postoperative complications between high and low segments, the percentage of satisfaction between the two groups with barbs, and the VAS score between the two arms of the first assistant were compared using *t*-test. The ratio of prevertebral soft tissue width change, operative time course and DNRS score were also compared with *t*-test. Statistical significance was set at $P < 0.05$.

Results

Prevertebral Soft Tissue Width Change Rate

The preoperative and postoperative X-ray radiographs contrasts of the application of two kinds of retractors in single and double segments as well as three segments are shown in Fig. 3. The measurement of prevertebral soft tissue width was presented in Fig. 4A. Among them, the prevertebral soft tissue width change rates after the application of the traditional S retractor with single ($P = 0.006$) and double ($P = 0.002$) segments were larger than those after the application of CCRS retractor, and the differences were of statistical significant. However, there was no significant difference in the rate of change induced by the two kinds of retractors in multi segment surgery ($P = 0.092$). Additionally, the results also revealed no correlation between the rate of change in prevertebral soft tissue width and the operative time ($P = 0.178$).

Comparison of Postoperative Complications

The overall frequency of dysphagia or dyspnea was 15.9% in the two study groups. As shown in Fig. 4B, the incidences of dysphagia and dyspnea in the conventional S retractor group were all significantly higher than those in the CCRS group. Postoperative complications were in line with the surgical segments, which with a higher incidence of complications in the high segment group (C4/5 and above) compared with the low segment group (C5/6 and below). There was no significant correlation between the rate of change in prevertebral soft tissue width and the DNRS score ($P = 0.092$). Except two severe dyspnea patients (one in each of the traditional S retractor and CCRS groups), the remaining patients with complications were all restored to normal by 1 week after symptomatic management. Moreover, the width change rate of cervical prevertebral soft tissue in single, double and three segments was compared with each other (Fig. 4C). The width change rate of cervical

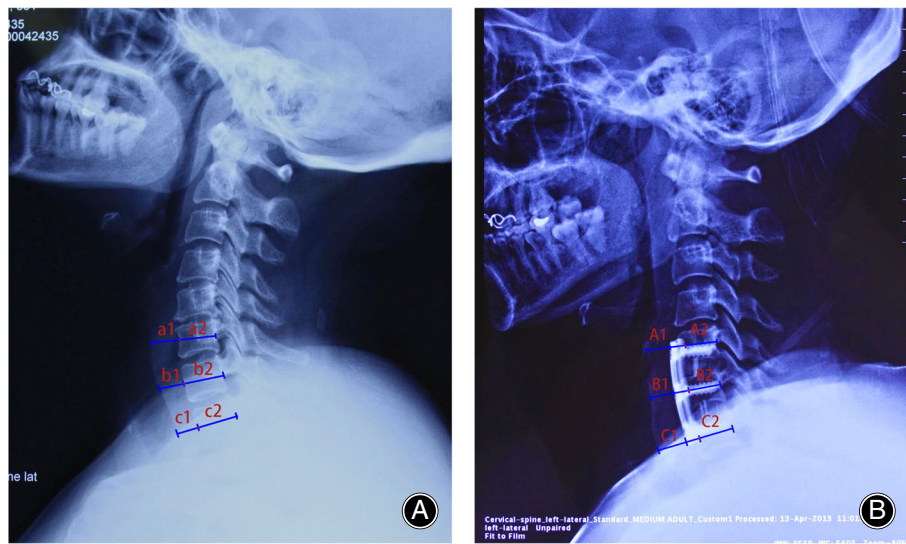


Fig. 2 The methods of measuring the width change rate of cervical prevertebral soft tissue. First, determine the middle point of the related upper and lower end plate of the vertebral body at the front of the vertebra (indicated by red point). Following make a vertical line to the front of the vertebral body through this point, by to the front of the anterior soft tissue of the vertebral body and to the posterior edge of the vertebral body. The preoperative (A) and postoperative (B) soft tissue width was measured respectively and the change rate was calculated. Taking a double segment ACDF as an example: on the preoperative X-ray radiography (A), a1, b1, and c1 represent the width of the soft tissue in front of the vertebral body, while a2, b2 and c2 represent the width of the vertebral body. On the postoperative X-ray radiography (B), A1, B1, and C1 represent the width of the soft tissue in front of the vertebral body, while A2, B2 and C2 represent the width of the vertebral body. So the change rate of prevertebral soft tissue width can be presented as $(A1/A2-a1/a2 + B1/B2-b1/b2 + C1/C2-c1/c2)/3$

prevertebral soft tissue in single and double, single and three segments were not presented with significance. Whereas three segments cervical surgery was of diminished width change rate of cervical prevertebral soft tissue compared to double segments cervical surgery.

Intraoperative Subjective Experience Comparison

As shown in Table 1, the percentage of postoperative satisfaction in the CCRS group were significantly higher than those in the conventional S retractor group ($P < 0.001$), while VAS scores were lower than conventional S retractor group with statistical significance ($P < 0.001$).

Discussion

This study demonstrated that CCRS was superior compared to traditional S retractor in reducing the postoperative complications and the postoperative fatigue of surgeon by focusing on the swelling severity of cervical prevertebral soft tissue, throat symptoms, and subjective experiences of the operating surgeons between using the traditional cervical S retractor and CCRS in ACDF.

Caspar Retractor in ACDF

As is well known, anterior cervical surgery is of high risk in spinal operations due to entering along the space between carotid sheath and esophagus trachea by a small incision and the anatomy of the operative site is very intricate and

perilous.⁴ It is easily to lead to edema of adjacent tissues and organs upon injury during the operative exposing, resulting in a series of complications, including dysphagia, dyspnea, pharyngeal discomfort, even bleeding, shock and death. The Caspar pins and vertebral distractor was invented in 1979 and remains regarded as key instruments for disc space preparation during ACDF.¹⁰ As standardized tools are lacking in three fundamental parts like wound exposure, decompression and fusion, fixation, a Caspar-based vertebral distractor was tailored. After application of the Caspar retractor, problems with poor screw placement and loosening as well as associated surgical complications were reduced. The retractor Caspar docks directly into the vertebral bodies rather than disc space, allowing surgeons to gain complete exposure of the disc space. It gains the eased osteophyte resection during anterior foraminotomies as corroborated by Brodke and Zdeblick in 1992.¹¹ As no reports have revealed the comparisons between the traditional S retractor and Caspar retractor systems, we herein studied this project and present the results accordingly.

Postoperative Complications in ACDF

Dysphagia is one of the most common complications in the early stage after anterior cervical surgery and its incidence varies from 1% to 79% according to previous reports.^{5,12} Numerous prospective studies demonstrated that the vast majority of these symptoms are transient and could be

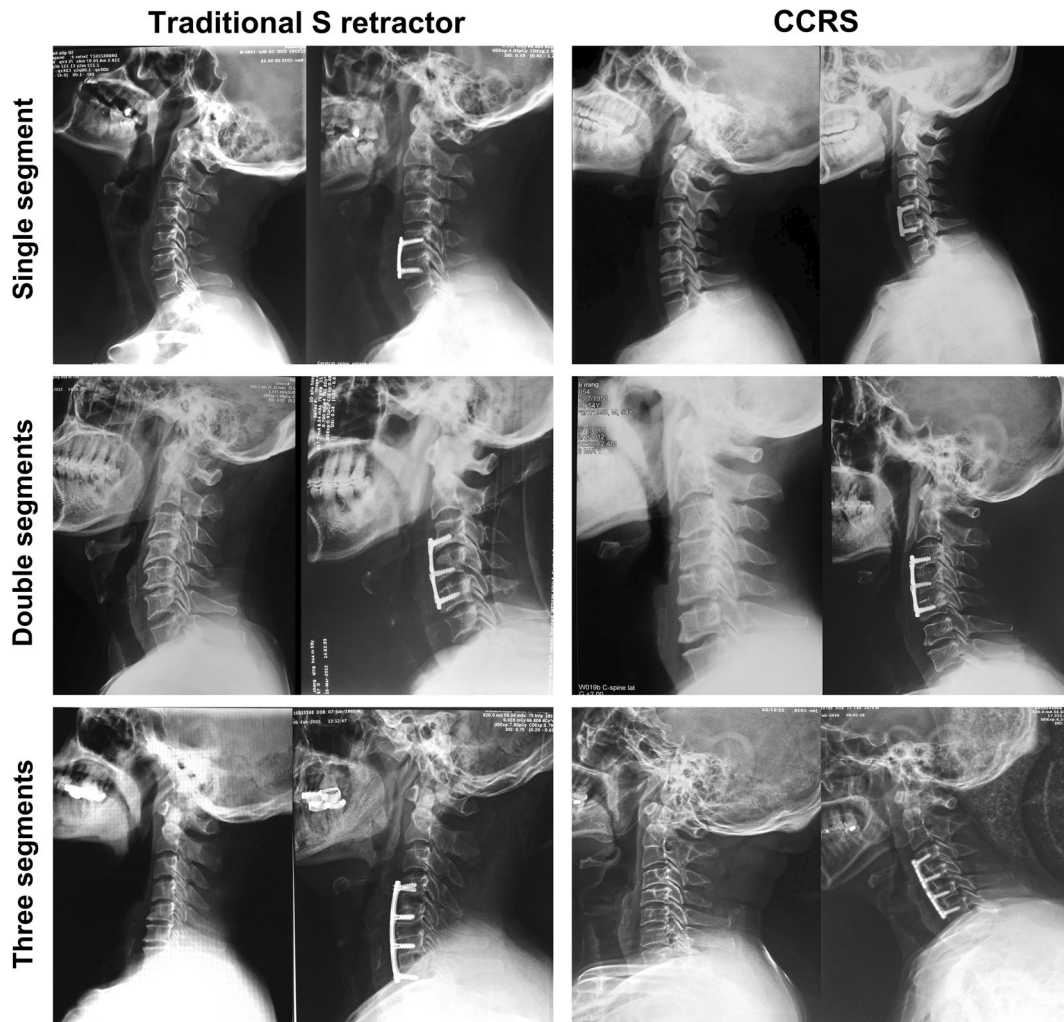


Fig. 3 Typical comparative images in single segment, double segments and three segments surgery

promptly improved after related symptomatic treatment.^{13,14} Dysphagia after anterior cervical surgery has become a research hotspot in recent years. Rihn *et al.* proposed that the reasons for swelling of the anterior vertebral soft tissue might be related to recurrent laryngeal nerve paralysis, esophageal ischemia-reperfusion injury and local edema, whereas the major pathogenesis is still obscure.¹⁵ Several studies suggested that the possible causes of short-term dysphagia are the swelling of soft tissue and esophageal wall after surgery, albeit there is still no definite correlation.^{6,16} Likewise, airway injuries comprising pharyngeal edema, pseudomembranous bulge, hematoma, vascular edema are also a complication that should not be ignored in anterior cervical surgery even if its incidence is hardly seen.¹⁷⁻²⁰ Andrew *et al.* confirmed that the probability of edema at the upper cervical level was higher than that at other cervical levels by measuring the width of the soft tissue shadow in the anterior vertebrae rely on the lateral X-ray of cervical spine.²¹

CCRS Reaches Pharyngeal Complications in ACDF

In the current study, we found that the postoperative pharyngeal complications were related to the surgical segment. The incidence of complications in the high segment group (C4/5 and above) was higher than that in the low segment group (C5/6 and below). This may be related to the local anatomical characteristics of the cervical spine. The high cervical spine corresponds to the pharynx and hypopharynx, and the posterior potential retropharyngeal space is relatively large, while the low cervical spine correlates to the esophagus and trachea.^{22,23} There are many soft tissue constraints and small potential lacunae, so the probability of postoperative soft tissue edema is higher.²⁴ In addition, we implied that there was no correlation between the change rate of prevertebral soft tissue width and DNRS score, which was in accord with previous study.¹⁶ Moreover, there was no correlation between the change rate of prevertebral soft tissue width and the operation time. Taken together, it can be concluded that the reason of dysphagia is not only related to the swelling of prevertebral soft tissue.

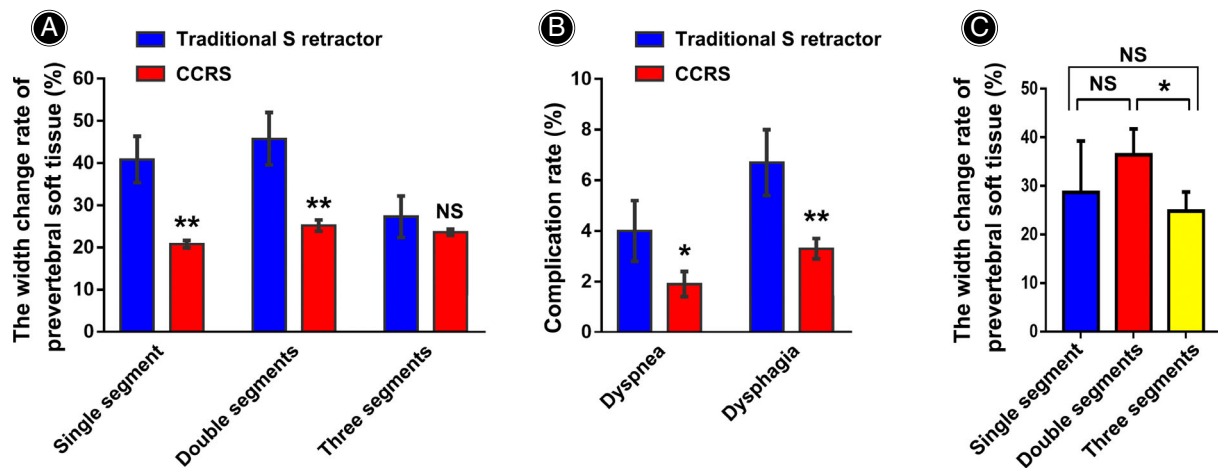


Fig. 4 The width change rate of cervical prevertebral soft tissue in different groups (A) and the comparison of complication incidence rate (B). The width change rate of cervical prevertebral soft tissue in single, double and three segments was compared with each other (C). * $P < 0.05$, ** $P < 0.01$. NS, not significant

CCRS Reduces Anterior Soft Tissue Width in ACDF

It is difficult for the assistant to maintain the traction force and position continuously by using the traditional S retractor during a long operation, so that the airway and esophagus and other soft tissues are repeatedly stimulated, which is easy to cause postoperative edema and increase the risk of surgery.²⁵ As to how to improve the operation and surgical instruments to reduce the risk of surgery has become a key point in anterior cervical surgery.^{26,27} The CCRS retractor is placed by the operator according to the size and depth of the incision after fully exposing the anatomical position.²⁸ Once the fixation is opened, a working channel with blade protection around it is formed, which generally does not need to be adjusted, this eventually reduces the repeated traction of tissues and organs in front of the cervical spine, and therefore increases the safety of the operation.²⁹ In this study, we found that the change rate of anterior soft tissue width of the traditional S retractor was significantly higher than that of the CCRS group after single level and double level anterior cervical surgery, which indicates that the application of the CCRS retractor in ACDF is more conducive to reducing the swelling of anterior vertebral soft tissue. However, there was no significant difference between the two groups in multi segmental surgery, which may be related to the larger incision and wider exposure range, thus reducing the degree of soft tissue traction in both two groups. Additionally, the incidence of dysphagia and dyspnea in traditional S retractor group was significantly higher than that in CCRS retractor group. The postoperative complications are related to the operative segments, which indicates that CCRS retractor is safer and less invasive than traditional S retractor in practical application in terms of not only beneficial to reduce the swelling of prevertebral soft tissue but also with protective effect on esophagus and trachea.

CCRS Improves Surgeon's Satisfaction

The vibration, compression and slight dislocation of the vertebral body will aggravate damage to the spinal cord, which can lead to serious consequences.³⁰ It is difficult for the assistant to maintain the traction force and position continuously when the traditional S-hook is used to expose the incision of anterior cervical surgery. The operation inevitably causes vibration and even compression or traction of the spinal cord.³¹ Furthermore, there is more bleeding during the operation and the operation field is not clear. The CCRS retractor makes the operation part into a relative stable ensemble and less bleeding on the operation site, and clear operation field. Its non-sliding toothed hook pulling piece can firmly fix the soft tissue, avoid it penetrating into the field, and eliminate iatrogenic injury. The safety of operation is increased, and the wider retractor piece reduces the pressure of surrounding soft tissue, and reduces postoperative complications.³² The CCRS retractor is beneficial to the exposure of the surgical field and increases the safety of the operation, and it also brings great ease of use for the operator. In this study, we added the subjective experience of the operator and found that the satisfaction of the operator and the VAS score of the first assistant in the CCRS group were better than those in the traditional S retractor group. This is because the CCRS retractor is easy to operate and the incision field of vision is clear. It is convenient for the surgeon's operation and reducing the work intensity of the first assistant, so as to reduce the fatigue of the operator's arms, which is also more conducive to the accuracy and safety of the operation.

Strengths and Limitations

This retrospective study with a ten year span is the first to identify that CCRS is superior to the traditional S retractor in ACDF, and gives the basic evidence to support the validation from both patients and surgeons. However, the

considerations of patients were different while the surgeons were stationary, so the subjective experience of operators could be further evaluated in different centers.

Conclusion

By comparing the swelling severity of cervical prevertebral soft tissue, throat symptoms, and subjective experiences of the operating surgeons between using the traditional cervical S retractor and CCRS in ACDF, this study concluded that CCRS was superior compared to traditional S retractor in reducing the postoperative complications and the postoperative fatigue of surgeon. Meanwhile, the width change rate of prevertebral soft tissue was not related with operative time and DNRS score.

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Author Contributions

Lianlei Wang and Cheng Qiu contributed equally on this study. Xinyu Liu and Suomao Yuan participated in the study design. Lianlei Wang, Cheng Qiu, Yonghao Tian, Junxiao Su, Hao Li and Zhihao Ma collected data. Lianlei Wang and Cheng Qiu analyzed the data and co-drafted the manuscript. Xinyu Liu revised the manuscript and supervised this study.

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