A Modified Open-Door Laminoplasty with Reconstruction of the Cervical Posterior Ligamental Complex to Decrease Axial Pain in Cervical Spondylotic Myelopathy

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Research article

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Abstract

Background:

Cervical spondylotic myelopathy patients with multiple segments are usually treated with the posterior approach. But expansive open laminoplasty (ELAP) often results in heavy, rigid, and acid bilges feelings in the neck, shoulder, and back, collectively known as axial symptoms.

Objective:

To evaluate the effect of modified posterior cervical ligament complex reconstruction and single-door laminoplasty with titanium plate fixation on postoperative axial symptoms in patients.

Methods:

A retrospective analysis conducted from June 2016 to March 2018 collected more than 132 cases of cervical spondylotic myelopathy at our institute. Group A includes 74 patients and Group B includes 58 patients who use different surgery method. Gender, age, operation time, intraoperative blood loss, post-operative drainage volume, and follow-up time, Visual analogue scoring (VAS), cervical curvature index (CCI) and the cross-sectional area of the posterior cervical muscles of the two groups were recorded.

Results:

There was statistical significance in the incidence of axial pain 3 months after surgery (P =0.001), 6 months after surgery (P =0.006), and 1 year after surgery (P =0.015). And the VAS score was decreased in group A 1 week (P <0.0001), 1 ,3 month(P=0.0001), 6 months(P=0.0076), and 1 year(P=0.0085) post-surgery compared to group B. Also the CCI and the posterior cervical muscle area between groups A and B (P < 0.0001).

Conclusion:

Modified single open-door laminoplasty could relieve cervical axial pain in patients with cervical spondylotic myelopathy.

1. Introduction

Cervical spondylosis is a syndrome characterized by a series of symptoms and signs due to various reasons that lead to the imbalance of cervical soft tissue and dynamic and static balance, which stimulates or compresses the cervical nerve roots, spinal cord and blood vessels. Cervical spondylosis is currently divided into four types: cervical spondylotic myelopathy (CSM), cervical spondylotic radiculopathy (CSR), arteria vertebralis type (AVT), and sympathetic cervical spondylosis SCS) [18].Various types of cervical spondylosis could produce different symptoms that generally anifest as neck and back pain, limb weakness, finger numbness, abdominal band feeling, lower limbs cotton feeling, walking difficulties, dizziness, vomiting, blurred vision, tachycardia, swallowing difficulties, and other symptoms[2; 25].When conservative treatment (including drugs, traction, acupuncture, massage, etc.) fails, surgery is an essential and effective treatment[6; 20]. For cervical spondylotic myelopathy with multiple segments (≥ 3 segments) (multiple cervical spondylotic myelopathy, MCSM)[11; 23], posterior decompression surgery is often used [8, 9]. Classic Hirabayashi open-door laminoplasty is a well-known procedure that treats cervical spondylotic myelopathy[4] usually leading to satisfactory recovery of spinal function. However, axial symptoms are the most frequent complications following this surgery[9]. Axial symptoms include heaviness, stiffness, and a sense of acid in the neck, shoulders, and back often causing pain and discomfort[5; 8; 10; 17]. Recent reports indicated that axial symptoms (neck and shoulder pain) could be related to damage to the cervical spinous process, posterior cervical ligaments, interspinous ligaments, and supraspinous ligaments[5; 19; 24]. To relieve the axial symptoms, we modified single open-door laminoplasty with reconstruction of the posterior spinous ligamental complex. We reconstruct the stability of the posterior cervical ligamental complex by retaining the spinous processes and reattaching them. This study assessed whether this modified surgical method could effectively relieve axial symptoms and identified the factors that improve post-operative axial symptoms.

2. Materials And Methods

This is a retrospective cohort study. This study is a single center study that located in Qilu hospital of Shandong University, which is a public, national top tertiary center general hospital. A total of 132 patients with cervical spondylotic myelopathy at our institute from March 2016 to March 2018 were included in this study. Inclusion criteria: Imaging data from multiple segments cervical myelopathy (≥3 segments)(multiple myelopathy, MCSM). Exclusion criteria: other types of cervical spondylosis were excluded, and the exception of cervical spondylotic myelopathy (<3 segments). Group A patients (Including 74 patients) who underwent modified single open-door laminoplasty with titanium plate fixation and reconstruction of the cervical posterior ligamental complex. Group B patients (Including 58 patients) who underwent the same open-door laminoplasty with fixation but without reconstruction of the cervical posterior ligamental complex. We set the postoperative follow-up time as 1 year after the operation. The outcomes were assessed using the cervical curvature index, VAS score, and cross-sectional area (CSA) of the erector muscle on CT scanning.

2.1 Surgical technique

Modified single open-door laminoplasty was designed to preserve the spinous process, supraspinal ligament, and unilateral paravertebral muscles. A midline skin incision is made from C3 to C6. C2 and C7 are preserved because many posterior cervical muscles are attached to them. Part of the bottom of the C2 and C7 spinous process are removed by air drill to decompress a longer buffer for the backward movement of the spinal cord. The unilateral paravertebral muscles of the open side are dissected and the ipsilateral laminae exposed. The spinous processes is cut at the base using bone shears. The contralateral paravertebral muscles and separated spinous processes are peeled off from the laminae to make a gutter on the hinge side. The lamina door is lifted, and a titanium micro-plate is placed to prevent its closure. The cut spinous processes, cervical posterior muscles, and ligaments are reset to the laminae and firmly sutured.

2.2 General evaluation index

Age, operation time, intraoperative blood loss, postoperative drainage volume, and follow-up time of the patients in groups A and B were observed and compared.

2.3 Axial symptoms (AS)

Visual analogue scoring (VAS)[16] was used to compare axial symptoms in the patients in groups A and B before surgery, 1 week post-surgery, 1, 3, and 6 months post-surgery, and 1 year post-surgery. A score of 0 indicates no pain, 1-3 indicates mild pain (sleep is not affected), 4-6 indicates moderate pain (sleep is affected), and 7-10 indicates severe pain (sleep is severely affected). A VAS score greater than 4 indicates severe axial pain. The incidence of axial pain, severe axial pain, and VAS scores in the same time period were statistically compared between the two groups.

2.4 Cervical curvature index (CCI)

The CCI was measured using the ISHI-Hare[7] method. All of the patients were connected from the C2 to C6 vertebral posterior margin on X-ray before and after surgery, called the R line. The R line was perpendicular to the posterior edge of the C3, C4, and C5 vertebrae. Their distances are respectively expressed as r1, r2, r3, and CCI = $\Sigma ri/R$. The preoperative and post-operative CCI values of the two groups were statistically compared.

2.5 Measurement of the muscle cross-sectional area (CSA) of the posterior cervical spine

The cross-sectional area of the posterior cervical muscles was measured using a method previously described by Fujimura[7]. The cross-sectional area of the posterior cervical muscles at the level of C3/4, C4/5, and C5/6 discs was measured by Photoshop on preoperative and post-operative CT films respectively, the total area of the muscles at the back of the cervical vertebra was measured by 3 cross-sectional areas, the cross-sectional area and total cross-sectional area of the two groups were statistically compared.

2.6 Statistical method

The relevant data collected were analyzed by SPSS 24.0 statistical software. Pearson's correlation analysis was used for the correlation data. The measurement and counting data were tested using the t test and x test, respectively. $P > 0.05$ indicated no statistically significant difference. $P < 0.05$ indicated statistically significant differences (*$P < 0.05$, **$P < 0.01$, and ***$P < 0.001$).

3. Results

The patients were followed up effectively. Group A includes 74 patients and Group B includes 58 patients. Two patients in group A died 50 and 60 days after surgery due to respiratory and digestive diseases. One patient in group B died 30 days after surgery due to digestive system disease, and the follow-up was terminated.

3.1 Comparison of preoperative and post-operative imaging data of all patients in groups A and B

All of the patients in groups A and B achieved bone healing (Postoperative imaging showed no bone defect or edema around the internal implant, and the position of the internal fixation was satisfactory) after post-operative review. There was no loosening, slipping, or fracture of the internally fixed titanium plates and screws. None of the patients presented with increased neurological symptoms. The preoperative and post-operative imaging data of the patients in groups A and B were compared (Fig 1).

3.2 Comparison of operation time, intraoperative blood loss, post-operative blood loss, and follow-up time between groups A and B

There was no statistically significant difference in the operation time between groups A and B (Table1 and Fig 2（1）). This might suggest that the operation time of patients in group A and Group B was not different due to different surgical methods.

There was no statistical significance in the comparison of the intraoperative and post-operative blood loss between groups A and B (Table 1 and Fig 2（2）). This might suggest that the intraoperative and post-operative blood loss of patients in group A and Group B was not different due to different surgical methods.

The patients in both groups were followed up for 12 months. However, 2 patients in group A died at 50 and 60 days after surgery due to respiratory and digestive diseases. One patient in group B died 30 days after surgery due to digestive system disease, and the follow-up was terminated (Table 1 and Fig 2

(3)).This might suggest that the follow-up time of patients in group A and Group B was not different due to different surgical methods.

3.3 Comparison of the incidence (%) of AS and severe AS (%) in the male and female patients in group A

There were 54 male and 20 female patients in group A presenting axial pain before surgery, 1 week after surgery, 1, 3, and 6 months after surgery, and 1 year after surgery. We compared the incidence of axial pain over time and found no statistical difference (Table 2 and Fig 3a). This might suggest that there is no difference between male and female patients in group A in the occurrence of axial pain.

The incidence rates of severe axial pain in the male and female patients in group A before surgery, 1 week after surgery, 1, 3, and 6 months after surgery, and 1 year after surgery respectively were compared. The results showed no statistical significance (Table 2 and Fig 3b). This might suggest that there is no difference between male and female patients in group A in the occurrence of severe axial pain.

3.4 Comparison of the incidence (%) of AS and severe AS (%) in the male and female patients in group B

There were 41 male and 17 female patients in group B presenting axial pain before surgery, 1 week after surgery, 1, 3, and 6 months after surgery, and 1 year after surgery. We compared the incidence of axial pain over time and found no statistical differences (Table 3 and Fig 4a). This might suggest that there is no difference between male and female patients in group B in the occurrence of axial pain.

The incidence rates of severe axial pain in the male and female patients in group B before surgery, 1 week after surgery, 1, 3, and 6 months after surgery, and 1 year after surgery respectively were compared. The results showed no statistical significance (Table 3 and Fig 4b). This might suggest that there is no difference between male and female patients in group B in the occurrence of severe axial pain.

3.5 Comparison of the incidence (%) of AS in groups A and B

The incidence of axial pain in groups A and B was not statistically significant before surgery, one week after surgery, and one month after surgery, but was statistically significant 3 months, 6 months, and 1 year after surgery (Table 4 and Fig 5). This might suggest that the incidence of axial pain was different between groups A and B with the extension of postoperative time.

3.6 Comparison of the incidence (%) of severe AS in groups A and B

The incidence of severe axial pain was compared between groups A and B. Except for no statistical significance before surgery, all of the other periods were statistically significant (Table 5 and Fig 6). This might suggest that the incidence of severe axial pain was different between groups A and B with the extension of postoperative time.

3.7 VAS scores of patients in groups A and B were compared

We compared the VAS scores in the patients in groups A and B. The preoperative VAS score had no statistical significance, but every other period of time had statistical significance. One week after surgery, 1 month after surgery, and three months after surgery, the *P* value was less than 0.001. Six months after surgery, the *P* value was less than 0.01. One year after surgery, the *P* value was less than 0.05 (Table 6 and Fig 7). This might suggest that there is a difference in the severity of postoperative axial pain between group A and Group B.

3.8 Comparison of the CCI values between groups A and B before and after surgery

The preoperative and post-operative CCI of groups A and B were compared between groups and within groups. The preoperative CCI values of the patients in groups A and B were not statistically significant, while the post-operative CCI values of the patients in groups A and B were statistically significant. The preoperative and post-operative CCI values of the group A patients were not statistically significant, while the preoperative and post-operative CCI values of the group B patients were statistically significant. We also compared the preoperative and post-operative CCI values of the patients in groups A and B. There was a significant statistical difference between the two groups (Table 7 and Fig 8). This might suggest that the comparison of post-operative CCI values of patients in group A and Group B was difference due to different surgical methods.

3.9 Comparison of the muscle area of the posterior cervical vertebra between groups A and B before and after surgery

We compared the preoperative and post-operative changes in the posterior cervical muscle area between groups A and B. The statistical comparisons of the C3/4, C4/5, and C5/6 levels and the total posterior cervical muscle areas were statistically significant (Table 8 and Fig 9). This might suggest that the comparison of muscle area of the posterior cervical vertebra of patients in group A and Group B was difference due to different surgical methods.

4. Discussion

Cervical spondylosis is a degenerative disease. The main causes are chronic fatigue, cervical disc herniation, osteogenesis, arthritis, ligament thickening and ossification, and trauma. These disorders cause severe clinical symptoms due to compression of the spinal cord, nerve roots, vertebral arteries, and sympathetic nerves[27]. Cervical spondylosis is divided into four types: cervical spondylotic myelopathy, cervical spondylotic radiculopathy, arteria vertebralis type, and sympathetic cervical spondylosis[12]. For most patients, conservative symptomatic support with medication, acupuncture, traction, and massage could relieve symptoms, but for a few patients, conservative treatment cannot relieve their symptoms, which could be further aggravated over time, causing significant pain. Posterior cervical surgery has been used as an alternative method since the 1950s to treat cervical spondylosis. The advantage of posterior cervical spine surgery is that it avoids damage to the trachea, esophagus, important blood vessels, and nerves in front of the cervical spine, hus reducing the risk of surgery[3]. However, the posterior cervical spine also has its own defects, often breaking down in the rear of the cervical muscle ligament complex, resulting in the destruction of the cervical vertebra rear anatomical structure and loss of stability, often causing post-operative stiffness, acid bilges, and pain in the neck, shoulder, and back, called axial symptoms (AS)[10]. After decades of development, single open-door laminoplasty has become a major surgical method for the treatment of multilevel cervical spondylotic myelopathy[1]. To alleviate axial symptoms after surgery, this surgical method has been continuously improved in clinical work, including posterior reconstruction, minor invasive surgery, and internal fixation [14; 21; 22]. In reconstructive surgery, expanded laminoplasty with preserved posterior spinous ligament complex proposed by Kawaguchi et al. could significantly alleviate axial symptoms in patients after surgery[15]. This modified surgical method restores the anatomical structure of the back of the cervical vertebra as much as possible, increasing the stability of the cervical vertebra after surgery, guaranteeing the physiological curvature and post-operative mobility of the cervical vertebra.

We conducted this retrospective study to further explore whether modified single open-door laminoplasty with reconstruction of the posterior spinous ligament complex (MLRP) has a significant effect on relieving axial symptoms after surgery and explore the possible factors leading to this result. Through statistical analysis of the collected data, we found that the occurrence, incidence, and severity of post-operative axial pain were not correlated with the age, gender, operation time, intraoperative blood loss, and post-operative drainage volume of patients. In terms of the post-operative VAS scores, there was no statistical difference in the incidence of axial pain 1 week and 1 month after surgery between groups A and B; however, the difference was significant 3 months, 6 months, and 1 year after surgery. The procedure did not reduce the incidence of post-operative axial pain in the first month post-surgery. But during the next follow-up from 3 months to 1 year, the incidence of axial pain in group A was significantly lower than in group B. No patients in group A suffered from severe axial pain again from 1 month after surgery, while the patients in group B still suffered from severe axial pain until 1 year after surgery.

Generally speaking, compared with traditional single open-door laminoplasty, the modified surgical method with reconstruction of the posterior spinous ligament complex has obvious advantages in relieving patients' post-operative axial pain. The post-operative axial pain in group A was significantly lower than in group B.

To study the reasons leading to this advantage, we measured the preoperative and post-operative X-rays of the patients in groups A and B, calculated the cervical curvature index (CCI) value of the patients, and conducted a statistical comparison. In group A, the comparison of the CCI values before and after surgery was not statistically significant, while in group B, the comparison of the CCI values before and after surgery was statistically significant, and the comparison of the CCI changes between the two groups was also statistically significant. This proves that traditional single open-door laminoplasty significantly changes the curvature of patients' cervical vertebra because of instability and destroys the posterior cervical muscle-ligament complex and spinous processes. The instability of the cervical spine after single open-door laminoplasty was regarded as the main reason for the reduction in post-operative axial pain, leading to post-operative rehabilitation.

However, MLRP may protect the muscles and ligaments that maintain the stability of the cervical spine. We observed preoperative and post-operative CT slices on the cervical back muscle cross-sectional areas. The results showed that the change in the value of the posterior cervical muscle cross-sectional area in group A was significantly lower than in group B, which may have been because simple single open-door laminoplasty destroyed the adhesion point of the muscle behind the spinous process, leading to significant post-operative muscle atrophy. This may be another important factor in the relief of post-operative axial pain in patients who undergo MLRP.

This retrospective study confirmed that MLRP could be of considerable significance in relieving patients' axial pain after surgery. Two relative factors are post-operative changes in the cervical curvature index and the cross-sectional area of the posterior cervical muscles. MLRP protects the posterior cervical muscles and prevents instability of the cervical spine via the reconstruction of the posterior cervical muscle-ligament complex and spinous processes. This study provides a novel alternative surgery to decrease axial pain in patients with cervical spondylotic myelopathy.

Conclusion

The incidence and severity of postoperative axial pain were significantly lower after modified single open-door laminoplasty with reconstruction of the posterior spinous ligament complex than the simple single open-door laminoplasty. This result could be related to changes in the cervical curvature index and the degree of atrophy of the posterior cervical muscles affected by the reconstruction of the posterior spinous process ligament complex of the cervical spine.

Declarations

Conflicts of Interest Declaration

There is no conflict of interest regarding the publication of this paper.

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Ethical Approval:

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Tables

Due to technical limitations, tables are only available as a download in the Supplemental Files section.

Figures

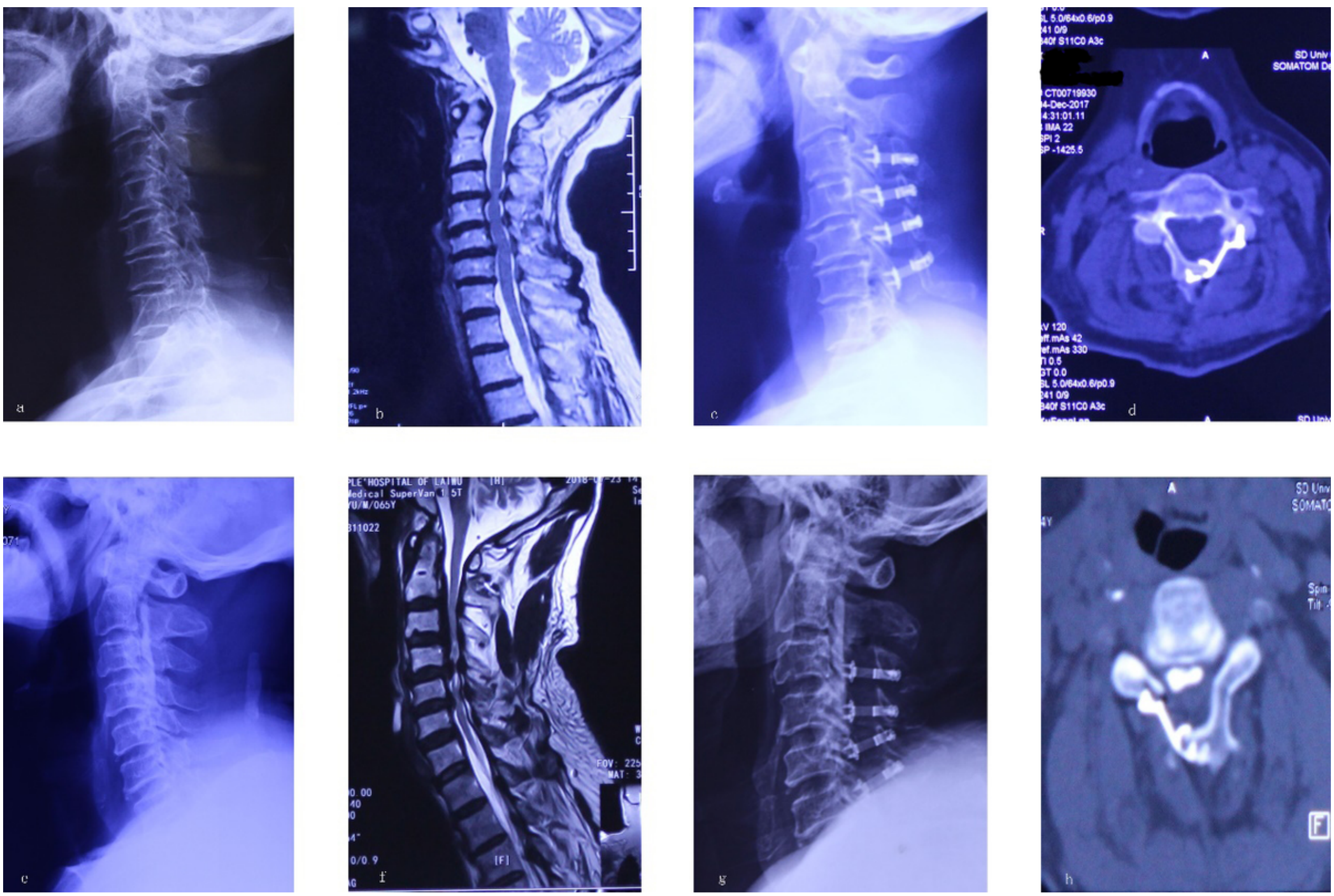

Figure 1

Comparison of preoperative and post-operative imaging data between groups A and B. All of the patients in group A (a and b) and group B (e and f) met the diagnostic requirements of multilevel cervical spondylotic myelopathy (MCSM). The patients in group A underwent single open-door surgery with the posterior spinous ligament complex preserved (c and d). The patients in group B underwent traditional single open-door surgery without retaining the posterior spinous ligament complex of the cervical spine (g and h).

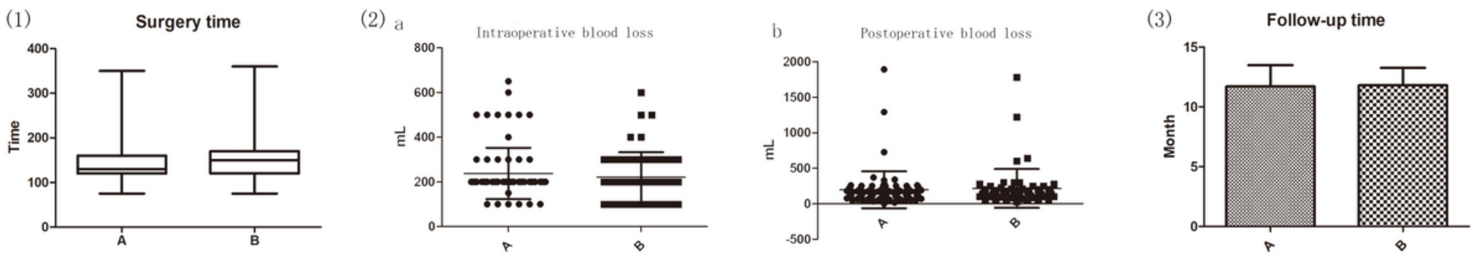

Figure 2

(1). There was no significant difference in the operation time between the two groups (*P < 0.05, **P < 0.01, and ***P < 0.001). (2). There was no statistical significance in the intraoperative and post-operative blood loss between groups A and B (*P < 0.05, **P < 0.01, and ***P < 0.001). (3). The follow-up times of patients in groups A and B were compared without statistical significance (*P < 0.05, **P < 0.01, and ***P < 0.001).

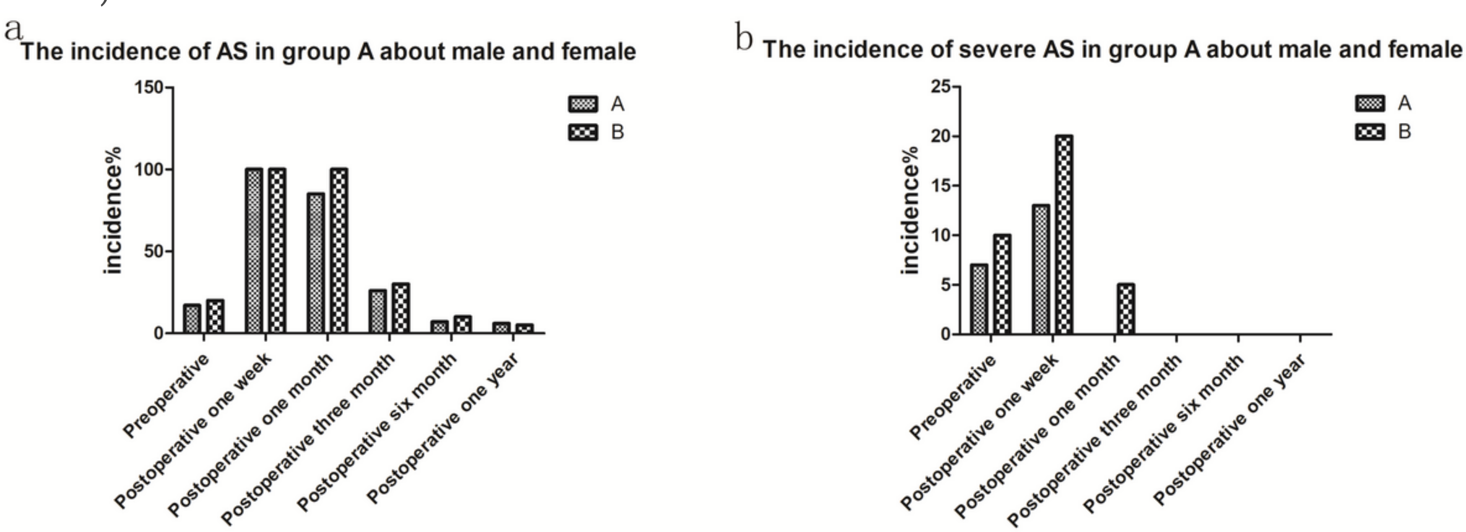

Figure 3

a. The incidence of AS in group A was compared among the male and female patients preoperative, post-operative one week, post-operative one month post-operative three months, post-operative six months, and post-operative one year. No statistical significance was found in each time period (*P < 0.05, **P < 0.01, and ***P < 0.001). b. The incidence of severe AS in group A was compared among the male and female patients preoperative, post-operative one week, post-operative one month post-operative three months, post-operative six months, and post-operative one year. No statistical significance was found in each time period (*P < 0.05, **P < 0.01, and ***P < 0.001).

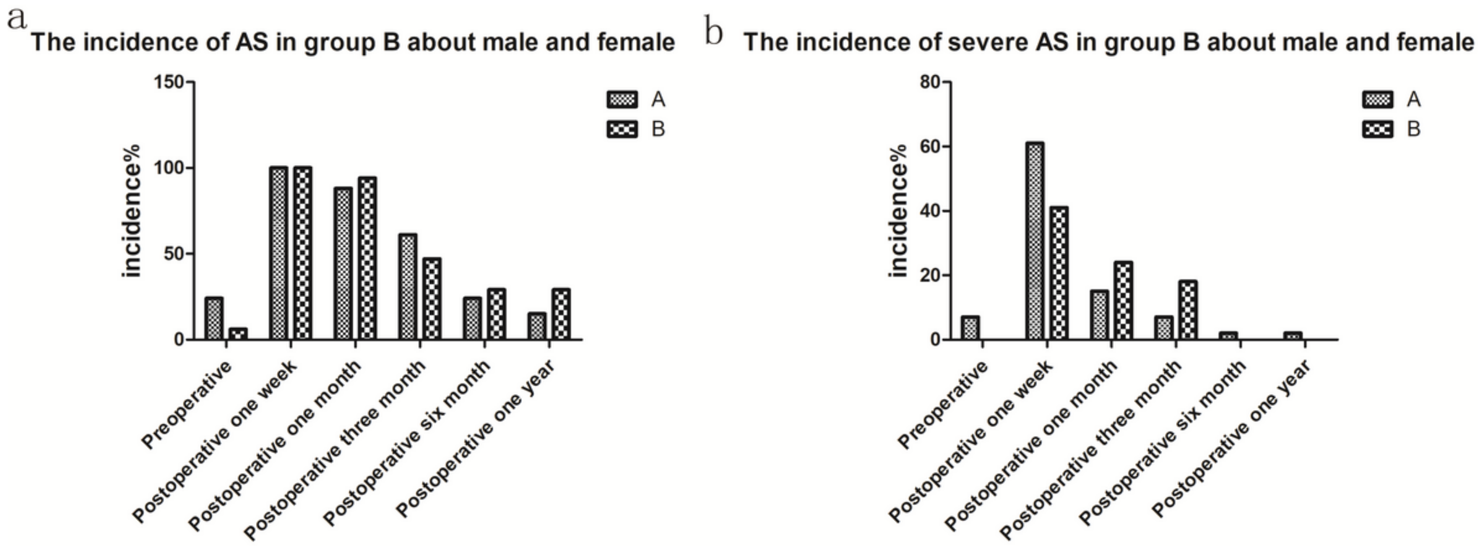

Figure 4

a. The incidence of AS in group B was compared among the male and female patients preoperative, post-operative one week, post-operative one month post-operative three months, post-operative six months, and post-operative one year. No statistical significance was found in each time period. (*P < 0.05, **P < 0.01, and ***P < 0.001). b. The incidence of severe AS in group B was compared among the male and female patients preoperative, post-operative one week, post-operative one month post-operative three months, post-operative six months, and post-operative one year. No statistical significance was found in each time period (*P < 0.05, **P < 0.01, and ***P < 0.001).

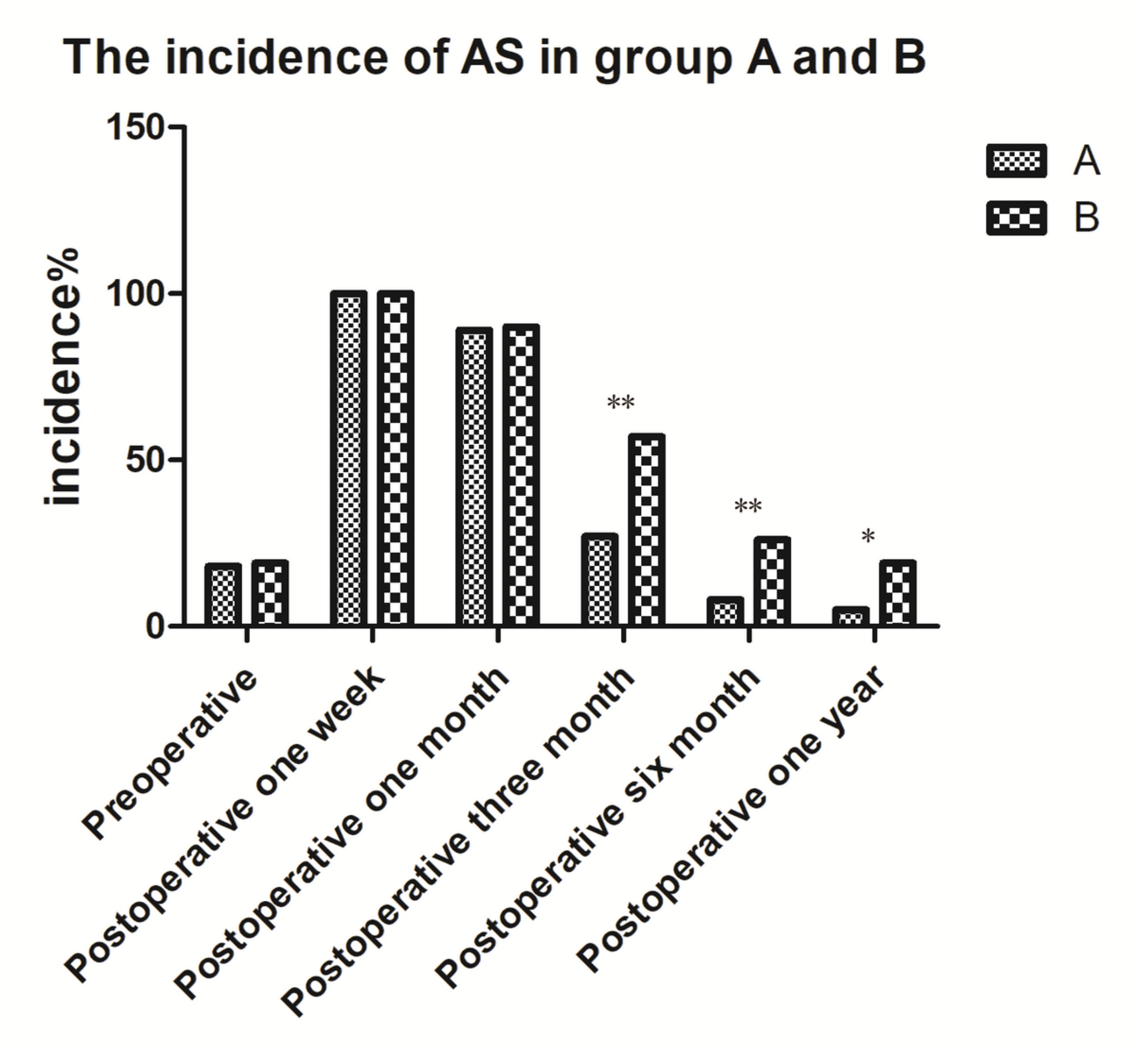

Figure 5

There was no significant difference in the incidence of AS between groups A and B before surgery, one week after surgery, and one month after surgery, but there was significant difference between groups A and B three months, six months, and one year after surgery (*P < 0.05, **P < 0.01, and ***P < 0.001).

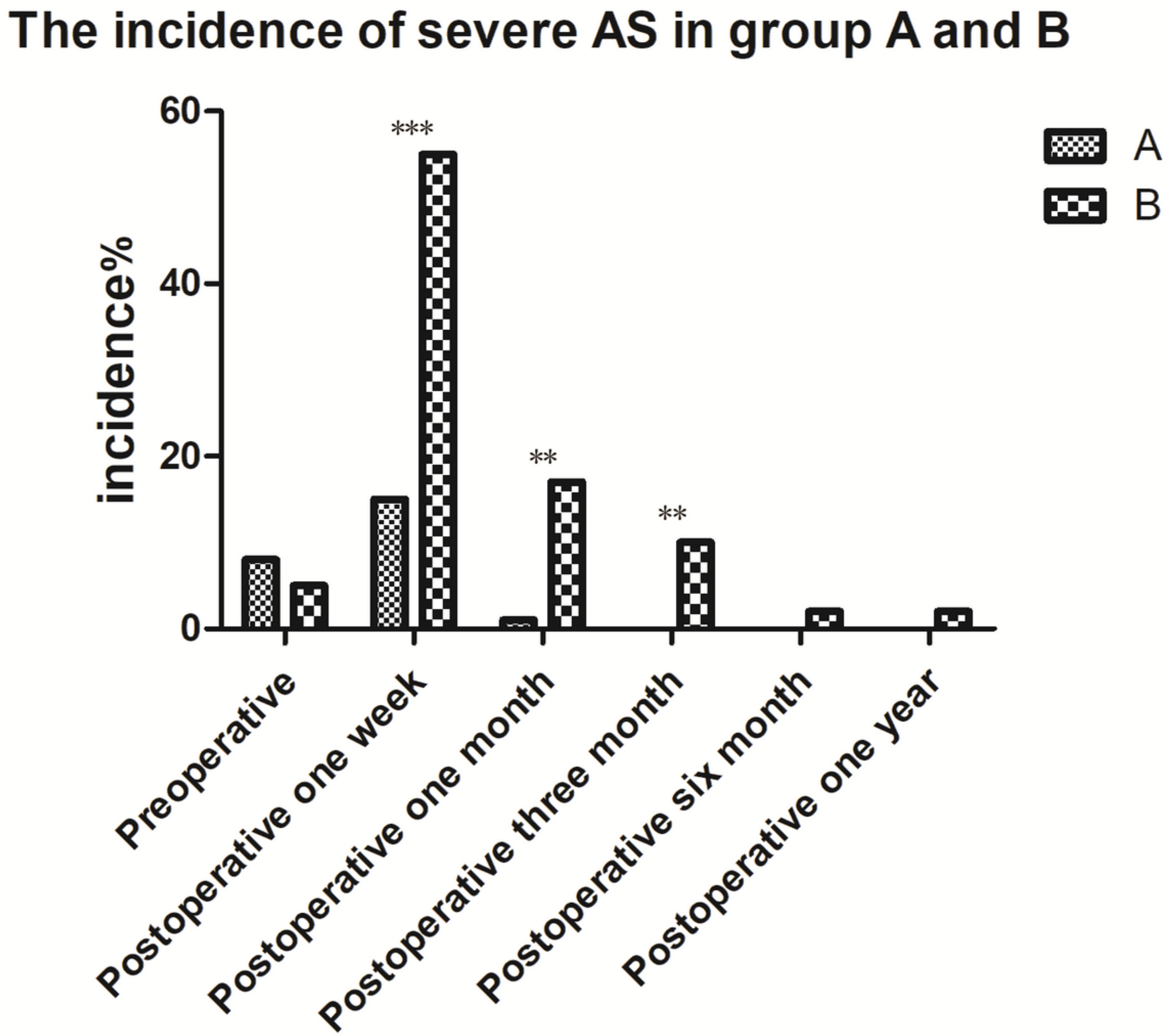

Figure 6

There was no significant difference in the incidence of severe AS between groups A and B before surgery, but there was a significant difference between groups A and B one week after surgery and one month and three months after surgery. There was no statistical difference between six months and one year after surgery, but it was essentially statistically significant because the patients in group A had no severe axial symptoms during this period, while the patients in group B still had them (*P < 0.05, **P < 0.01, and ***P < 0.001).

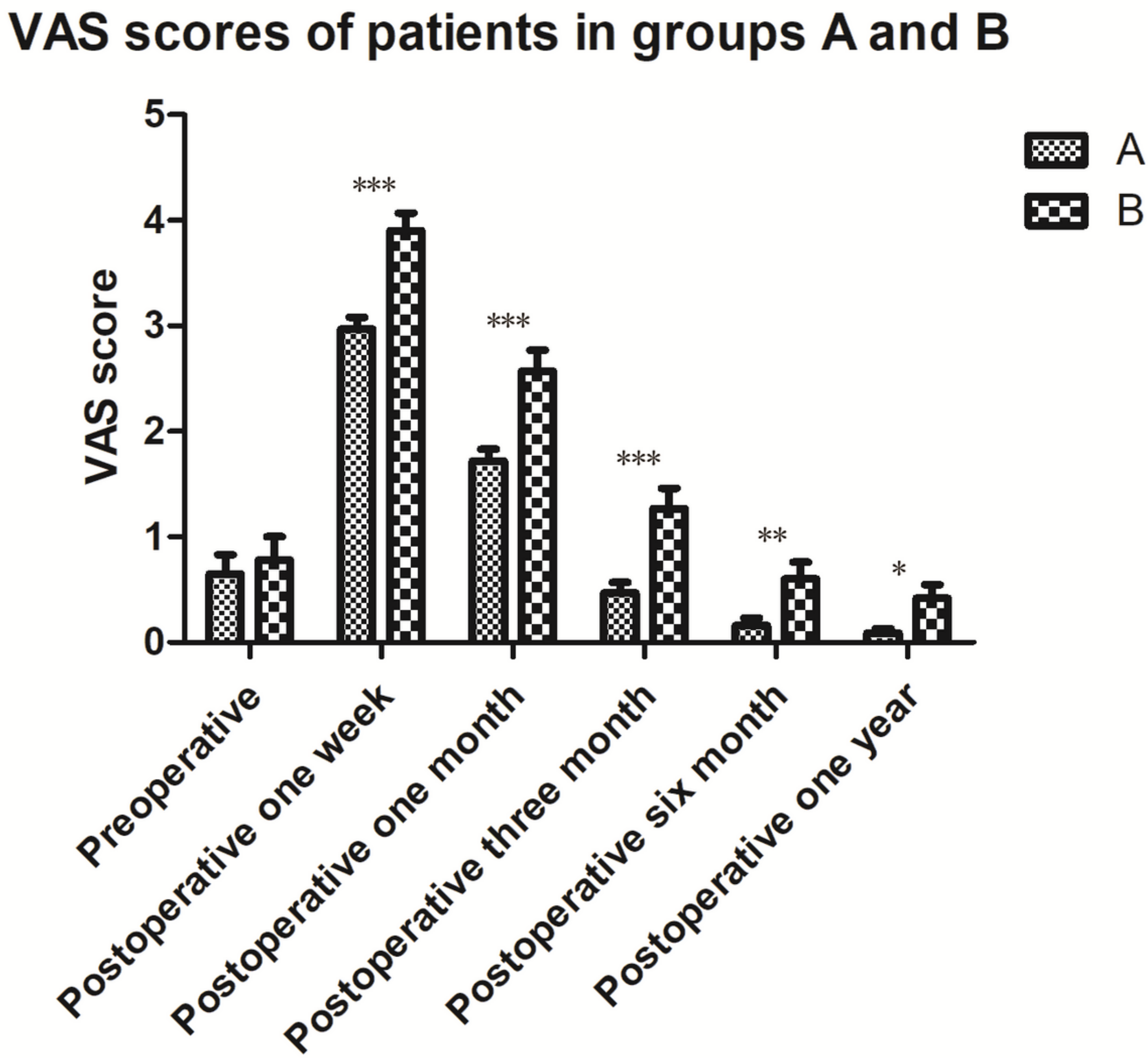

Figure 7

The VAS scores of the patients in groups A and B showed no statistical difference except preoperative comparison, and the other time periods showed statistical difference (*P < 0.05, **P < 0.01, and ***P < 0.001).

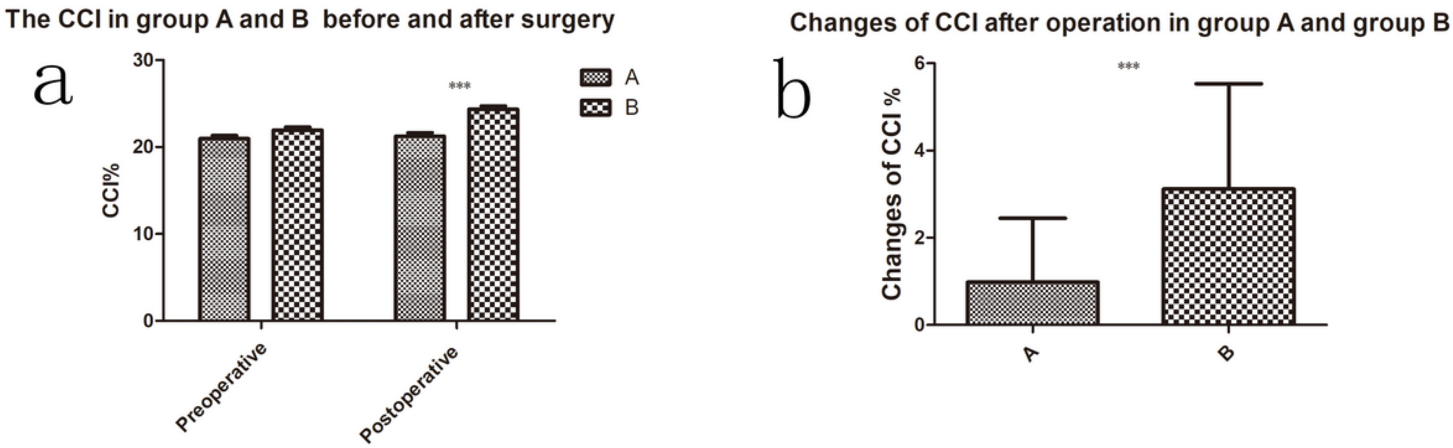

Figure 8

a. Preoperative and post-operative CCI values of the patients in groups A and B were compared. b. The changes in the CCI in groups A and B before and after surgery were compared (*P < 0.05, **P < 0.01, and ***P < 0.001).

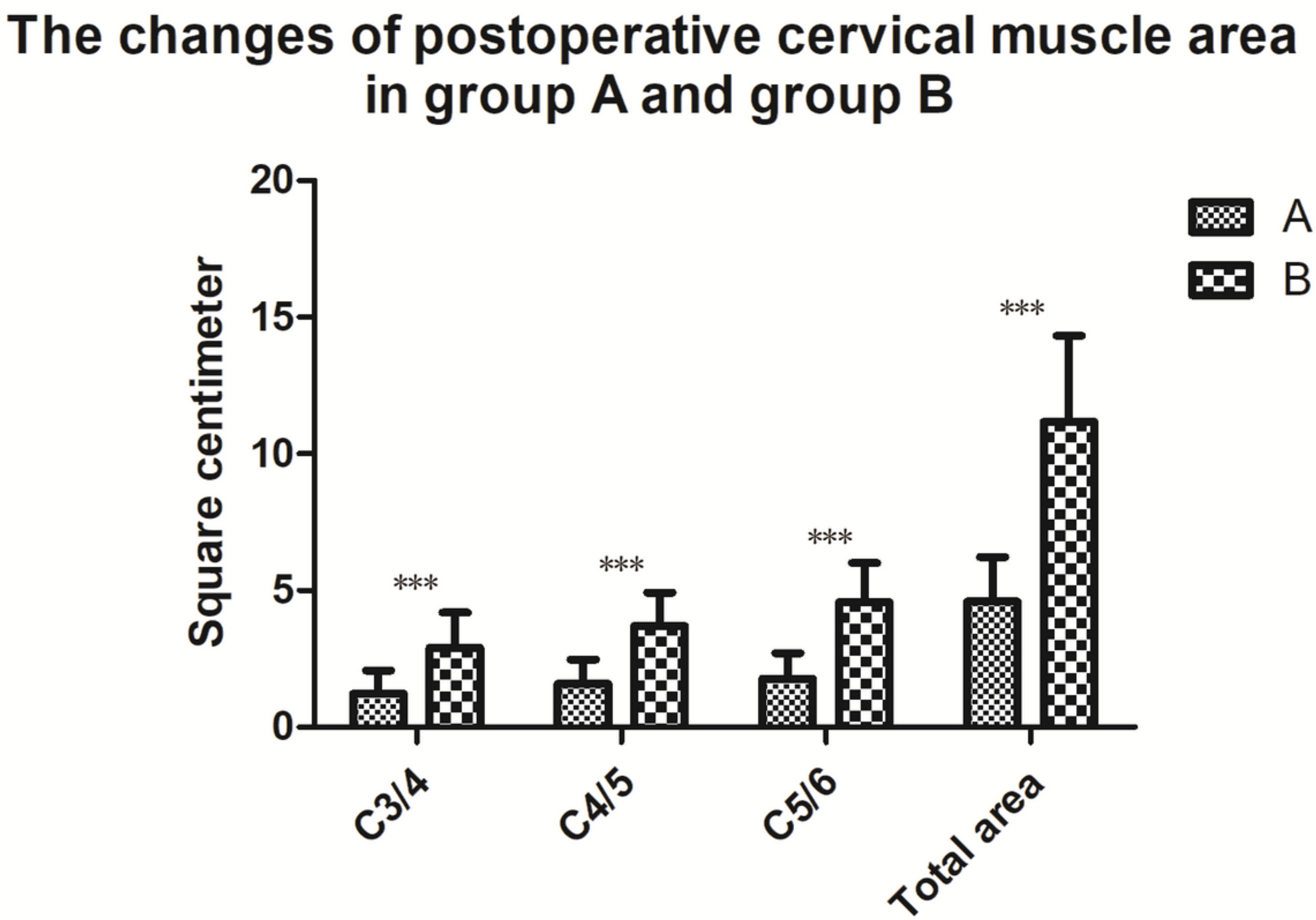

Figure 9

There were statistical differences in preoperative and post-operative changes in the cervical posterior muscle area between groups A and B (*P < 0.05, **P < 0.01, and ***P < 0.001).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1.doc
- Table2.doc
- Table3.doc
- Table4.doc
- Table5.doc
- Table6.doc
- Table7.doc
- Table8.doc