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Original Article

A comparative study of clinical efficacy of thoracoscopic surgery, traditional open chest anterior approach and posterior approach on adolescent idiopathic scoliosis

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Abstract: Objective: To evaluate the clinical efficacy of three surgical methods: thoracoscopic surgery, traditional open chest anterior approach and posterior approach on scoliosis correction. Methods: A total of 60 adolescent scoliosis cases with surgical treatment from January 2010 to June 2016 were retrospectively analyzed. According to their operation methods, they were divided into three groups: thoracoscopy group (T group), open chest group (OC group) and posterior group (P group) with 20 cases in each group. The perioperative parameters (operating time (min), intraoperative blood loss (mL), the lengths of hospital stay (d), postoperative 24 h Visual Analogue Scale (VAS) pain scores), postoperative upper extremities functional scores, corrective efficacy of scoliosis and the complications of patients were recorded. The excellent rates of symptoms reduction and the condition of the interbody fusion were observed in the follow-up period. Results: The blood losses in T group (250±35.2 mL) were less than those in OC group (365±40.5 mL) and those in P group (360±51.2 mL) (all P<0.001). And the VAS pain scores were lower in T group as well (all P<0.001). Although the operating time was longer in T group, the lengths of hospitalization were significantly decreased (all P<0.001). The postoperative upper extremities functional scores were higher in T group than in OC group and in P group (all P<0.001). The postoperative excellent and good rates of symptoms reduction in T group, OC group and P group were 75.7%, 80.0% and 78.6% respectively (P=0.676). All the cases showed good osseointegration. The average correction rates of scoliosis Cobb angle in T group, OC group and P group were 55.05%, 59.87% and 60.55% respectively (P=0.972). Conclusion: Good surgical efficacy can be achieved by thoracoscopy, traditional open chest anterior approach and posterior approach. Meanwhile, thoracoscopic surgery has obvious advantages in the reduction of intraoperative blood loss, pain, upper extremities disorders and so on.

Keywords: Adolescent idiopathic scoliosis, clinical efficiency, thoracoscopic surgery, open chest anterior approach, posterior approach

Introduction

Adolescent idiopathic scoliosis (AIS) is one of the most common spinal deformities among children and adolescents. It is an unknown-caused three-dimensional spinal deformity which harms the health of children and adolescents. The incidence rate of AIS is high in china and abroad with a potential development trend. Severe scoliosis deformity can take place in some patients without timely treatment [1]. Surgical treatment, which has quick and short course of treatment, can largely and quickly correct the patient's spinal deformity. It is one of the most common therapy methods for patients with severe scoliosis [2, 3]. Surgical methods generally include traditional open chest anterior approach, posterior approach and new thoracoscopic spine surgery.

In 1993, Mack, as the first person, applied thoracoscopy in anterior spine surgery [4]. With an increasing number of clinical applicable cases all over the world and the gathering experience, now it is a common idea that thoracoscopic surgery has several advantages such as reduced trauma, decreased postoperative wound pain, weakened scapular dysfunction and shortening the lengths of hospital stay. Furthermore, it can avoid the potential risks caused by the traditional open chest surgery with big incision. Generally, the treatment and the reconstruction

Table 1. Comparison of subjects' clinical data among T group, OC group and P group

	Cases	Age (year)	Height (cm)	Cobb angle	Gender	
					Male	Female
T group	20	14±1.3	146±3.6	55.3±6.1	9	11
OC group	20	13±2.1	148±5.5	56.4±2.3	10	10
P group	20	14±1.5	148±3.1	57.3±5.1	8	12

of lesions are easily to be done with the help of thoracoscopy for lesions of short segment. But as for long segment operations, such as the anterior scoliosis correction and thoracoscopic spine surgery are often limited. Picetti designed orthopedic instruments specifically for microscopic correction of scoliosis, but its clinical efficacy needed further observation [5]. Therefore, it is necessary to analyze and compare the clinical efficacy and complications of thoracoscopy-assisted, open chest anterior and posterior scoliosis correction, so as to provide a convincing basis for clinical treatment.

We have performed systematic comparison among three surgical methods: thoracoscopy-assisted, open chest anterior and posterior traditional approach. The perioperative parameters (operating time (min), intraoperative blood loss (mL), the lengths of hospital stay (d), postoperative 24 h VAS pain scores), postoperative upper extremities functional scores, corrective efficacy of scoliosis and the complications of patients were recorded. The excellent rates of symptoms improvement and the condition of the interbody cage were observed in the follow-up period. Therefore, we can explore the value of the clinical application of these three methods on scoliosis correction.

Materials and methods

Materials

This study was approved by the Hospital Ethics Committee and obtained consents from patients and their families. Sixty adolescent scoliosis cases (including 27 males and 33 females, age: 9-16 years old, mean age: 14 years old, preoperative height: 135 cm-175 cm, average height: 147 cm) with surgical treatment from January 2010 to June 2016 were retrospectively analyzed. There were 15 cases of the apical vertebral of lateral thoracic curve being located at T6 vertebral body in the image of full-length spine, 15 cases at T6-7 gap, 12 cases at T7 vertebral body, 9 cases at T7-8 gap and 9 cases at T8 vertebral body. The Cobb angle was ranged from 45° to 68°, mean angle: 57.2°; Risser sign grade I-IV; rotational deformity (Nash-Moe method) was from degree I to degree III; the biggest skewing of plumb line drawn from apical vertebral to C7 spinous process was 2.4-8.5 cm, an average of 4.5 cm. All the patients had varying degrees of razor dorsal deformity, 45 with right scoliosis and 15 with left scoliosis.

Inclusion criteria: patients with idiopathic scoliosis and scoliosis Cobb angle from 45° to 70° and soft scoliosis, at the age from 9 to 16, with the weight more than 30 kg; patients without neurological symptom and any disorder in full-length spinal cord, spinal canal magnetic resonance imaging; patients without kyphosis, pneumonia, tuberculosis and history of open chest surgery; patients with normal lung function and who had one of the three surgeries, thoracoscopy-assisted, open chest anterior or posterior scoliosis correction; patients or their families who voluntarily participated in this study and signed the informed consent.

Exclusion criteria: patients with severe diseases such as heart disease, uremia, coagulation disorder; deformity in other body parts as well, primary infection at planned surgical incision site, mental illness, previous injury which need treatment and the treatment might disturb the assessment of efficacy and patients who were not willing to cooperate.

As for the grouping, sixty adolescents with idiopathic scoliosis were divided into T group (thoracoscopy-assisted small incision technique for anterior scoliosis correction), OC group (open chest surgery for anterior scoliosis correction) and P group (traditional posterior scoliosis correction), with 20 cases in each group. There was no statistical difference in clinical data among three groups, indicating the data were comparable (as shown in **Table 1**).

Methods

Thoracoscopic scoliosis anterior correction surgery: A double-lumen endotracheal tube was used after general anesthesia. A single

lung ventilation was selected according to the convex side of the scoliosis. Lateral position was applied. The upper extremity of the surgical side and elbow joint were raised, flexed 90° and then suspended. The hip and shoulder were fixed on the operation table in case that the intraoperative position changes affected the screw placement. Firstly, C-arm X-ray machine orthotopic and lateral perspective was performed to locate the radioactive projection of the upper and lower vertebrae and apical vertebral intervertebral space on the body surface to help correct the preoperative planned cannula channel position. Then an incision about 2 cm was cut at the 6th and 7th intercostal space to posterior axillary line (the body surface projection area of the apical vertebral intervertebral space). Next, the muscles and pleura were separated by bending pliers. And then the cannula was inserted to establish the observation channel and the insertion of thoracoscopic lens were performed to build the other two operation channels. The intervertebral space which needed operation was located by Kirschner wire after a complete collapse of the lung. After that, the posterior pleura of the intervertebral surface were cut by bipolar electric coagulation forceps, and the intervertebral disc was explored. The intervertebral disc and its adjacent cartilage were removed with bone knife and curette. A long-handled pneumatic grinding drilling was used to repair bone groove, which was then filled with the autogenous rib. And generally there were four intervertebral space length for epiphyseal arrest. All the operations of intervertebral space were on the front edge of the ribs, meanwhile, the vertebral blood vessels were released without cutting off and ligation. After completing anterior intervertebral epiphyseal arrest and bone graft, the entrance points were located by the Kirschner wire (the entrance points should be located in the front of rib, at the central vertebral body and parallel to the end plate). Small pieces of ribs were cut off for the three operation channels so that the two screws could be inserted into each of them. After completing the operations, closed thoracic drainage tube was placed in the lowest working channel. Then the pleural cavity was checked to ensure that there was no active bleeding and the channels were closed one by one. Closed thoracic drainage tube could be removed after 24-48 hours, when there was no liquid out.

Traditional open chest scoliosis anterior correction surgery: The operations of traditional open chest scoliosis anterior correction surgery and the thoracoscopic scoliosis anterior correction surgery were basically the same. The main significant difference was the size of the incisions. In traditional open chest scoliosis anterior correction surgery, the incision was usually 25 cm. The position was decided by the apical vertebral level. Generally, the position was 2 intervertebral space higher than the rib corresponding to the apical vertebral. In order to fully expose thoracic cavity, another rib needed to be removed and could be used as the corresponding bone graft material. In the surgery, the surgeon needed to open the apical vertebral incision, which was located at T6 and wrapped around the lower edge of the scapula.

Traditional posterior scoliosis correction surgery: The incision regularly was cut at the center of the back. After exposing the lamina of vertebra and articular processes and other accessories, the soft tissue of concave side was released. Pedicle screws were put in according to the preoperative X-ray and other imaging data. Then pressure of stenosis segment spinal canal and neural foramen decreased, therefore, the compressed nerve root was thoroughly released. Afterwards, the articular processes were removed and joint segments were split. While protecting the interior dural sac and ensuring that the anterior annulus fibrosus not exceeding the anterior longitudinal ligament, the intervertebral disc was removed. Due to the different kinds of deformities, different kinds of cages should be chosen. And in line with the implantation techniques of different kinds of cages, the cages were implanted in the corresponding parts. Finally, a stick which was pre-curved to a specific radian was applied to rotate and press in the convex side. The concave side was opened to expose the transverse process and the bone cortex was removed to carry out intertransverse bone graft.

Evaluation indexes

The perioperative parameters (operating time (min), intraoperative blood loss (mL), the lengths of hospital stay (d), postoperative 24 h

Table 2. Comparison of perioperative parameters among T group, OC group and P group

	Operating time(min)	Intraoperative blood loss (mL)	Hospital day (d)	VAS scores
T group (n=20)	200±18.1*,#	250±35.2*,#	10±3.2*,#	3.2±0.3*,#
OC group (n=20)	120±22.5	365±40.5	15±2.6	6.3±0.5
P group (n=20)	100±15.2	360±51.2	14±3.6	5.1±0.8
F	157.761	40.904	66.815	149.592
P	<0.001	<0.001	0.517	<0.001

Note: *vs. P group, P<0.001; #vs. OC group, P<0.001.

VAS pain scores), postoperative upper extremities functional scores, corrective efficacy of scoliosis and the complications of patients were recorded. The excellent rates of symptoms reduction and the condition of the interbody fusion were observed in the follow-up period.

As for the VAS pain scores, the degrees of pain were expressed by numbers 0-10 (a total of 11 figures): 0 for no pain, 10 for the most pain [6]. Patients selected one of the eleven figures to express the degree of their pain according to their own painful degree: 0 point for no pain, 1-3 points for mild pain which was bearable, 4-6 points for pain which could affect sleep and should be treated clinically, 7-10 points for strong pain which was unbearable. Upper extremities function was evaluated according to the Kendall Score, which included eight motor functions: flexion, extension, abduction, adduction, medial and lateral rotation of the shoulder joint, and flexion and extension of the elbow joint [7]. Each motion would be evaluated as different degrees using 5-point assessment method: 1 point for completely normal, 2 points for motor function decreasing ≤15%, 3 points for motor function decreasing 16%-30%, 4 points for motor function decreasing 31%-45%, 5 points for motor function decreasing 46%-60%. The improvement of Cobb angle was evaluated according to the efficacy before and after surgery. The specific methods were as follows. After confirmed the central vertebral body according to the X-ray film, two articular surface lines were drawn at the upper edge of the upper vertebral body and at the lower edge of the lower vertebral body. For each of the two lines, a vertical line was drawn, the intersecting angle of two vertical lines was the Cobb angle of the curve line [8]. Postoperative follow-up period was 6 to 48 months (mean 16 months), one follow-up was performed every six months. Clinical efficacy evaluation was according to the modified Japanese orthopaedic association back pain evaluation questionnaire [9]. Improvement rate = [(score before treatment - score after treatment)/score before treatment]*100%. Grading standards were: excellent, when improvement be equal or greater than 70%; good, when improvement rate was 50%-70%; medium, when improvement rate was 30%-50%; poor, when improvement rate was <30%.

Statistics

Statistical analysis was performed with SPSS 17.0. Mean ± standard deviation was used to express the measurement data. Univariate variance analysis and F test were used for comparison among the three groups. The measurement data of the two independent samples were detected by t test. Enumeration data were expressed by rates, and differences among the three groups as well as between the two independent samples were examined by χ^2 test. The difference was statistically significant when P<0.05.

Results

Comparison of perioperative parameters among T group, OC group and P group

Operating time of T group was 200±18.1 min, which was longer than that of OC group (120±22.5 min) and that of P group (100±15.2 min) (all P<0.001). The intraoperative blood loss in OC group and in P group were 365±40.5 mL and 360±51.2 mL respectively, while the intraoperative blood loss in T group (250±35.2 mL) was significantly reduced (all P<0.001). At the same time, compared to the other two groups, the hospital days (10±3.2 d) and the postoperative 24 h VAS scores (3.2±0.3) in T group were significantly decreased (as shown in **Table 2**, P<0.001).

Upper extremities function evaluation in T group, OC group and P group

The Kendall scores of the upper extremities function at surgery side were normal (1 point) in

Table 3. Upper extremities function evaluation in T group, OC group and P group

	After the surgery	3 months after the surgery	6 months after the surgery
T group (n=20)	1.3±0.3*,#	1.1±0.1*,#	1*,#
OC group (n=20)	2.1±0.2	1.5±0.3	1.3±0.2
P group (n=20)	2.2±0.3	1.4±0.2	1.2±0.1
F	66.364	18.571	28.000
P	<0.001	<0.001	<0.001

Note: *vs. P group, P<0.001; #vs. OC group, P<0.001.

Table 4. The corrective efficacy evaluation in T group, OC groupand P group

	Correction rate of Cobb angle	Height increasing (cm)
T group (n=20)	55.05%	3.4±0.5
OC group (n=20)	59.87%	3.6±0.6
P group (n=20)	60.55%	3.7±0.3
χ^2/F	0.057	2.301
P	0.972	0.613

60 cases before operation. The Kendall scores of T group were respectively 1.3±0.3, 1.1±0.1 and 1 in postoperative 24 hours, 3 months and 6 months. Those scores were significantly lower than those of OC group and P group (as shown in **Table 3**, all P<0.001).

The corrective efficacy evaluation in T group, OC group and P group

The average correction rates of scoliosis Cobb angle in T group, OC group and P group were 55.05%, 59.87% and 60.55% respectively (P= 0.972). The postoperative height increasing in T group, OC group and P group were 3.4±0.5 cm, 3.6±0.6 cm and 3.7±0.3 cm respectively (P=0.613) (as shown in **Table 4**).

Postoperative complications and the excellent rates of follow-up symptoms reduction in T group, OC group and P group

In the OC group, pulmonary infection occurred in two cases, with one side encapsulated effusion. It was improved by thoracic puncture and anti- inflammatory treatment. In P group, wound infection occurred in one case and also improved by anti-inflammatory treatment. There were no related complications in other cases. The follow-up period was 6 to 48 months (mean 16 months), an average of 6 months for each follow-up. The excellent and good rate of symptoms reduction was 75.7% in T group, 80.0% in OC group and 78.6% in P group (P=0.676). The increasing of the Cobb angles of all cases was less than 5° and all the cases got good osseointegration (as shown in **Table 5**).

Discussion

AIS is a kind of spine deformity that occurs before skeletal maturity. It seriously affects adolescents in their psychological, physiological functions, life and some other aspects. Without active or proper treatment, it can lead to premature degeneration of the spine, pain, somatic imbalance, spinal cord compression and even paraplegia [10, 11]. Scoliosis deformity in the thoracic segment may impair cardiopulmonary function. Children with severe deformity may even die because of the cardiopulmonary failure which shows in the early stage [12, 13]. There is a high incidence of AIS, which is very harmful to adolescents. Moreover, the surgical orthopedic instruments used are very complicated with high difficulty, heavy trauma and a lot of complications. It is one of the most difficult surgeries in pediatric orthopedic surgeries and has always been the focus of orthopedic surgeons.

In recent years, with the extensive application of thoracoscopic surgery in orthopedic surgery field and the continuous updating and progress of the thoracoscopic instruments, some scholars tried thoracoscopic anterior release, bone graft fusion and internal fixation. The ideal results were obtained. Scholars believed that it had advantages such as less trauma and fewer postoperative complications comparing with open chest surgery [14, 15]. In this study, the patients were divided into three groups according to the different types of surgery they treated with, including thoracoscopic correction surgery, anterior correction surgery or posterior correction surgery. We also confirmed thoracoscopic correction surgery could reduce the damage to upper extremities and quicken the recovery. The advantages were very significant.

Arlet et al. performed a meta-analysis of treating AIS by thoracoscopic surgery to anterior release. The preoperative scoliosis angle was from 50° to 80° (mean 65°). After thoraco-

Table 5. Postoperative complications and the excellent rates of follow-up symptoms reduction in T group, OC group and P group

	Postoperative complications				Excellent rate
	Atelectasis	Pulmonary infection	Pneumothorax	Wound infection	
T group (n=20)	0	0	0	0	75.7%
OC group (n=20)	0	2	0	0	80.0%
P group (n=20)	0	0	0	1	78.6%
χ^2					0.784
P					0.676

scopic anterior release and posterior fusion, Cobb angle was improved, which was from 55% to 63%. Patients were satisfied with the efficacy. But he believed that the follow-up period was short in current literature and the results of thoracoscopic release needed further prospective studies [16]. Reddi *et al*. who conducted a systematic retrospective analysis of the relevant literature, also found that thoracoscopic surgery had an equal correction rate to traditional anterior and posterior surgery. He held the idea that this surgery had minimally invasive advantages in theory, but further prospective studies were also needed [17]. This study increased the mean follow-up period to 16 months. Compared with anterior and posterior correction surgery, there was no difference in long-term excellent and good rates of symptoms reduction in patients who had thoracoscopy surgery. And in all the cases, Cobb angle increased little with good bone fusion. We confirmed the similarity in height increasing and scoliosis Cobb angle average correction rates in three groups. We also confirmed the minimally invasive advantages of thoracoscopic spine correction surgery, which had less intraoperative blood loss, shorter hospital days and decreased postoperative 24 h VAS scores. The treatment quality was significantly improved.

At the same time, it has been reported that using thoracoscopic techniques could reduce trauma compared with using open chest anterior approach, but it still damage the lung function in some degree. Related complications included atelectasis, pulmonary infection, pneumothorax, wound infection, etc. [18-20]. Therefore, we tried our best to reduce the occurrence of these complications by using more advanced thoracoscopic devices, more precise methods of operation and more reasonable surgical arrangements. The results showed that impeccable thoracoscopic spine correction surgery could effectively avoid complications. In contrast, two cases of pulmonary infection occurred in OC group because of the bigger trauma. And one case of wound infection occurred in P group.

In summary, thoracoscopic correction surgery, traditional open chest anterior surgery and posterior surgery can get good efficacy for scoliosis correction. Particularly, thoracoscopic surgery has significant advantages in reducing blood loss, pain and upper extremities dysfunction. At the same time, the relatively short follow-up period and relatively small sample size of this study may lead to bias results. We will further conduct prospective studies with more adequate sample size and longer follow-up period to confirm our conclusion, so that thoracoscopic correction surgery can be widely used in clinic.

Disclosure of conflict of interest

None.

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