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Surgical approach to idiopathic scoliosis: a systematic review with meta-analysis

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Abstract: Objectives: to analyze surgical approaches for the treatment of idiopathic scoliosis and the prognosis achieved. Methodology: A systematic review with meta-analysis was carried out using the electronic databases PubMed/MEDLINE and Cochrane Library. Results: The sample consisted of 217 patients with a mean age of 15 years diagnosed with idiopathic scoliosis. In all the studies included, the pathological curvature was reduced by more than 49%. Conclusion: The pathological curvature was reduced in all surgical interventions, and the short- and long-term post-operative results were satisfactory.

Keywords: Scoliosis; Adolescent; Surgical procedures.

Introduction: Adolescent idiopathic scoliosis is a spinal deformity comprising a lateral curvature in the frontal plane, thoracic lordosis in the sagittal plane and transverse vertebral rotation, resulting in posterior elevation of the rib cage on the convex side of the curve and a depression on the concave side. The rate of progression of this pathology is quite variable, while mild curves can result only in aesthetic problems, more severe curves can cause pain and more serious problems such as spinal imbalance and camptocormia.

This deformity can be caused by problems in the formation of the spine at the embryonic stage, or it can be part of certain syndromes. However, most cases of scoliosis are called "idiopathic" because the underlying cause cannot be determined. Adolescent idiopathic scoliosis is the most common form of spinal deformity in children and adolescents, with a prevalence of 1-3% in adolescents aged 10 to 16, a higher incidence in females and with almost 10% of patients requiring treatment, of which 0.1% require surgical treatment.

The diagnosis of adolescent idiopathic scoliosis is traditionally based on the Cobb method for assessing the curvature of the spine. This method measures the angle of the spine, and the diagnosis is made when the result of the Cobb angle is greater than or equal to 10 degrees. Depending on the age of the individual at diagnosis, scoliosis evolves and can deteriorate rapidly during periods of rapid growth spurt. Early diagnosis is difficult, often because the external changes in the early stages are minimal and most of the changes occur at the back of the torso and are hidden by clothing. Therefore, in the diagnosis, during the evaluation of the progression of the curve, all factors are taken into account in order to decide the best type of treatment for the patient.

Treatment strategies for adolescent idiopathic scoliosis can be conservative or surgical, the type of treatment being determined by the deformity itself. Conservative treatments are applied to patients with small curves and surgical treatment is recommended for those with severe curves.2, 4 That said, the aim of this study is to analyze surgical approaches to the treatment of idiopathic scoliosis and the prognosis achieved.

METHODOLOGY

This systematic review is registered on the PRÓSPERO platform under ID CRD42024572386. It is a systematic review with meta-analysis in which a bibliographic search was carried out using the electronic databases: PubMed/MEDLINE and Cochrane Library without language restriction of publications up to February 2024, using a search strategy combining keywords and MeSH terms and the Boolean operator AND/OR. The search terms "Scoliosis" AND "Adolescent" AND "Surgical Procedures" were used.

As this was a meta-analysis of published works, there was no need for approval by the ethics committee or institutional scientific review board. The reference lists of the included and previously published articles were searched for more relevant studies that met the eligibility criteria.

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines: 5

1. Population: Patients diagnosed with adolescent idiopathic scoliosis.

2. Intervention: Surgical treatment

3. Comparator: Comparison between the pre- and post-operative results of the established surgical interventions.

4. Results: Surgical intervention provides satisfactory results in the short and long term.

5. Study design: Randomized controlled designs, counterbalanced crossovers or repeated measures designs that investigated the effects of the recovery interval.

Inclusion and exclusion criteria

(01) studies evaluating the surgical treatment of idiopathic scoliosis in adolescents (2) patients aged between 12 and 18 (3) original retrospective studies and randomized clinical trials.

Studies with the following criteria were excluded: (1) experimental studies using animal models (2) non-original studies - literature reviews (3) opinion studies (4) studies which reported on the treatment of idiopathic scoliosis in other age groups (5) studies published more than ten years ago (6) studies which did not meet the other inclusion criteria mentioned above.

The search and selection of studies was carried out by two reviewers who analyzed the studies. Initially, studies published in the last five years (2020-2024) were selected using the aforementioned DECS and Boolean operators, followed by an analysis of titles and abstracts. At this stage, studies using animal models, opinion articles and literature reviews were excluded.

Once this stage had been completed, the full texts of the articles were retrieved for analysis of the other inclusion and exclusion criteria. Duplicate citations and studies not corresponding to the proposed review parameters were also excluded. Possible disagreements were resolved by discussion with a third reviewer, and inclusion was decided after consensus with the two main reviewers.

To prioritize methodological quality, studies classified as "Good" after the NIH quality assessment were included, with studies with more than nine items ticked being considered suitable for inclusion.

Epidemiological and demographic data was extracted using a Microsoft Excel spreadsheet, including parameters such as number of patients, surgical approach, risk factors described, infection prevention strategies.

RESULTS

The five studies selected were obtained by excluding articles that did not meet the inclusion criteria. Current studies analyzing surgical treatment for the correction of idiopathic scoliosis in adolescents were selected (Figure 1). A total of 217 patients aged 12-18 years were included.

The analysis of the variation in the greatest Cobb angle is shown in Table 1 and Figure 2.

Byun et al presented a study of 35 patients with a mean age of 14.9 years undergoing correction of idiopathic scoliosis by posterior spinal fusion, in which pulmonary function and correction in degrees of deviation were analyzed as outcomes. Forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1) were part of the pulmonary assessment. Of the study participants, 20 had impaired lung function as a result of the pathology. In this sample, the pre- and post-operative FVC values showed differences in the mean percentages of 66.1 ± 15.6% versus 70.7 ± 13.2% (p=0.29), and for FEV1 the variation was 79.2 ± 37.7% versus 81.1 ± 9.1% (p=0.60). It was observed that those who had no previous pulmonary impairment did not show significant variations in these parameters (p=0.63). The correction of the thoracolumbar curvature recorded was 45.7 ± 14.4º versus 20.0º ± 10.2º (p=0.06).

Zhang et al presented a study evaluating the correction of juvenile idiopathic scoliosis in 11 patients (4 males and 7 females) with a mean age of 13 years, using posterior surgical correction with halo-femoral traction. The follow-up period for these participants was 32 months. The preoperative Cobb angle was 139.01°± 5.83° and was reduced to 82.98°± 6.91° after surgery, a correction rate of 40.39%. The mean thoracic kyphosis angle (TK) varied from 65.02° ± 7.21° to 23.85° ± 5.14°, and lumbar lordosis (LL) from 39.05° ± 4.08° to 44.95° ± 2.26°. Pulmonary function was also assessed; the preoperative percentage of FVC% and FEV1% were 50.08% ± 6.07% and 53.46% ± 5.96%, respectively, while the postoperative values were increased to 65.45% ± 5.29% and 69.08% ± 5.32%. The average duration of the surgical procedure was 335.91 ± 48.31 minutes and blood loss was 1590 ± 520.1 ml.

Sapriza et al reported on the use of pedicle screws to correct adolescent idiopathic scoliosis in a longitudinal observational study, which included 19 patients. The follow-up period was nine years. The mean preoperative Cobb angle reported was 58°±3.0° to 23°±4.1° postoperatively, an improvement of 60%. With regard to patient satisfaction, only one patient reported feeling severe pain and 18% felt no pain at all. 90% reported being very satisfied with the surgical result, 95% had no limitations for sports or daily activities and 90% said they were satisfied with the aesthetic result.

Santos et al's study of 43 patients showed a mean Cobb angle of the greatest curvature preoperatively of 51.5° ± 13.7°, corrected to 16.5° ± 7.5° after surgery. Another relevant point was the difference in the measurement of the T1 profile inclination from 1.5 ± 0.6 to 0.60 ± 0.2 and the variation in neck inclination from 38.4 ± 11.4 to 36.8 ± 12.3. Some parameters did not show significant changes pre- and post-operatively, such as cervical lordosis.

Benli et al. presented a study of 109 patients, with an average age of 14, over a 136-month follow-up. As a primary outcome, the Turkish SRS-22 questionnaire showed values for general self-image 3.8±0.7, function 4.0±0.8, mental state 3.6±0.7, pain 3.6±0.8 and satisfaction 4.6±0.3. The mean Cobb angle of the main curves in the frontal plane was 60.8°±7.5°. The correction rate of the main curves was 38.7±22.1% post-operatively, with a mean overall loss of correction of 5.3°±5.8°. The largest curves showed correction of 38.7+/-22.1%, the average post-operative kyphosis angles in these cases was 37.7º +/-7.4 and for lumbar lordosis 36.3º±8.5 º. The complications reported were superficial infection in 2.8% of patients, and 3.7% of patients had neurological deficits, including one case of late distal paraplegia.

DISCUSSION

Idiopathic scoliosis is the most common spinal deformity in children and adolescents, and its treatment differs according to the degree of severity of the pathology. In severe idiopathic scoliosis, for example, the aim of treatment is to achieve an acceptable balance of the spine and save fusion levels. There are currently numerous surgical techniques for treating this deformity, including hybrid treatment and posterior spinal fusion. That said, in recent years the surgical method for scoliosis has progressed extensively and recently, the various imaging, navigation and robotic technologies available for spinal fusion surgery have increased significantly, facilitating through modern assistive technologies high precision in the placement of pedicle screws.

One of the surgical procedures used to correct adolescent idiopathic scoliosis is the posterior spinal fusion technique. This technique consists of posterior instrumental fusion after meticulous exposure of the posterior elements of the spine to the tips of the transverse processes on both sides. For the placement of the thoracic screw, a technique was used that allows inspection with a spatula inside the canal of the upper, medial and lower edges of the pedicle. In addition to the spatula inside the canal, the well-known anatomical landmarks are used to determine the entry point of the pedicle. The pedicle is placed using a small curette, applying gentle pressure for 30 mm in the proximal thoracic pedicles, 35 mm in the mid-thoracic region and 40 mm for the lower thoracic pedicles, directed along the axis of the pedicle in the frontal and sagittal planes. Metal pins are inserted into the thoracic holes and the screws are inserted with slow force using a screw diameter corresponding to 80% of the pedicle diameter.The direction of the screw is more convergent medially in the upper thoracic spine, convergent in the middle thoracic spine and straight at the levels of T11 and T12. Finally, screw placement is confirmed by fluoroscopy, using AP, lateral and oblique views.

Posterior spinal fusion surgery and the placement of screws can present additional difficulties, such as excessive screw penetration. However, the biomechanical advantages associated with their use make screws the ideal construction for better correction of scoliosis and restoration of thoracic kyphosis. In addition, research has shown that this technique has long-lasting and reliable results, preventing the progression of deformity and the decline of lung function. Regarding the postoperative period of this surgery, two points are important to note: changes in height after correction of the deformity and changes in activity level. Thus, it is known that after the procedure the patient's clinical and spinal height increases, in addition, the patient's activity decreases and the return to athletic activity is correlated with the distal level of fusion.

As previously mentioned, new treatment techniques for idiopathic scoliosis have emerged with advances in technology. Recently, a technique has emerged that is an advance on the “medial margin segmentation method” performed using the O-arm navigation system (Medtronic O-arm II). This technique consists of posterior exposure of the lumbar vertebra with transverse process (TP) through appropriate soft tissue dissection, thus a C-arm fluoroscope is gradually rotated until a true posterior-anterior view is obtained, allowing symmetrical visualization of both pedicles. For extremely small lobar pedicles (ESLPs), the pedicle shadows appeared as ellipses or long, thin lines, so an imaginary pedicle contour was assumed based on the elliptical or linear shadow. The entry point of a screw is established at a 2 o'clock position on the presumed pedicle contour. Then, after adjusting the appropriate convergence of the gear, both cortices of the transverse process were penetrated and the tip was advanced towards the lateral wall of the vertebral body. After creating an internal entry point from the body of the lateral cortex, all the bony edges are checked by palpation before and after tapping with a probe. Subsequently, an extrapendicular screw is placed in the vertebral body using tricortical fixation.

Some disadvantages and complications are to be expected with this new surgical technique, which include the possibility of irritation of the psoas muscle along the trajectory of the screw, resulting in symptoms such as a decrease in the degree of hip flexor muscle, pain or irritation of the lumbar plexus in the post-operative period. There is also the possibility of segmental artery injury and the risk of screw removal due to limited bone purchases. That said, there was no case of screw pull-out in this procedure, which was justified by the high bone density present in the group of young patients. Therefore, fixation strength for the correction and maintenance of scoliosis correction can be achieved using fixation involving only the PT and the vertebral body.

CONCLUSION

The pulmonary function analyzed by some studies showed a significant improvement in FEV1 and FVC in cases of severe AIS. Pathological curvature was reduced in all the studies that used posterior spinal fusion and showed good short- and long-term operative results.

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Figure 1- Studies selected according to the PRISMA methodology.

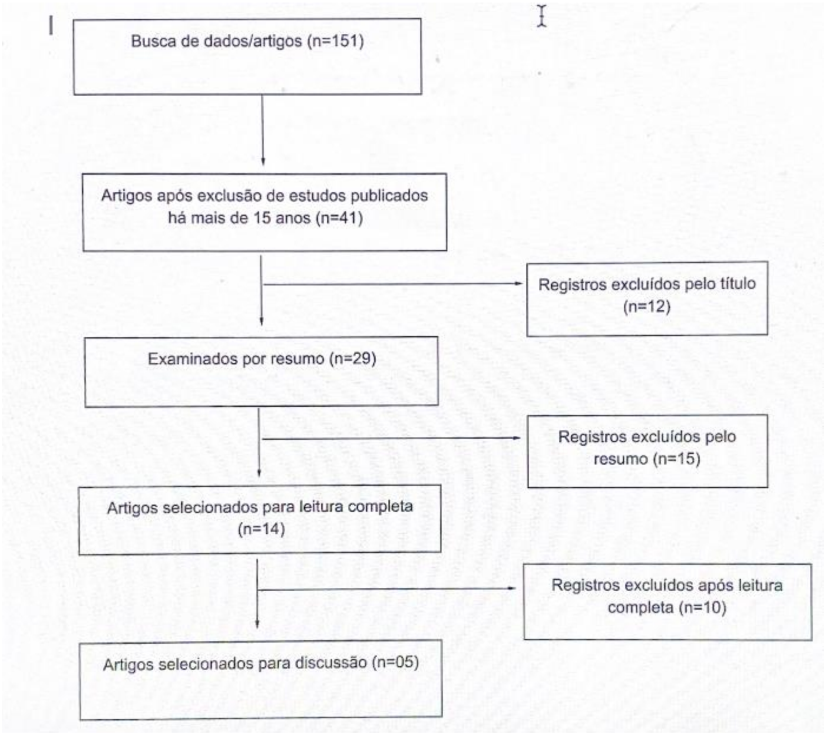

Table 1- Pre- and post-operative Cobb angles.

Estudo	Amostra	Ângulo Cobb pré operatório	Ângulo Cobb pós operatório
Byun e col	35 pacientes	45.7 ± 14.4º	20.0º ± 10.2º
Zhang e col	11 pacientes	139,01°± 5,83°	82,98°± 6,91°
Saprizze e col	19 pacientes	58°±3.0°	23°±4.1°
Benli e col	109 pacientes	60,8°±7,5°	25.3°±14.8°
Santos e col	43 pacientes	51.3º ± 14.9º	16.5º ± 7.5º

Figure 2- Forest graph of Cobb angle variations.