

# IMMEDIATE POSTOPERATIVE AND LONG-TERM RESULTS OF A MINIMALLY INVASIVE APPROACH FOR THE CORRECTION OF ADOLESCENT IDIOPATHIC SCOLIOSIS

*RESULTADOS PÓS-OPERATÓRIOS IMEDIATOS E A LONGO PRAZO DE ABORDAGEM MINI-INVASIVA PARA CORREÇÃO DE ESCOLIOSE IDIOPÁTICA DO ADOLESCENTE*

*RESULTADOS POSTOPERATORIOS INMEDIATOS Y A LARGO PLAZO DE UN ABORDAJE MINI-INVASIVO PARA LA CORRECCIÓN DE ESCOLIOSIS IDIOPÁTICA DEL ADOLESCENTE*

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## ABSTRACT

**Objective:** To analyze the results obtained with a new surgical technique for minimally invasive (MIS) isolated posterior approach to the surgical correction of adolescent idiopathic scoliosis (AIS). **Methods:** We compared two similar groups of patients with AIS of Lenke type 1A. The groups were similar in age, sex, Cobb angle, apex of the curve, vertebral rotation, thoracic kyphosis, fusion levels, type of instrumentation and follow-up. Group 1 was treated with a mini-invasive technique and Group 2 by the conventional method. We analyzed surgery time, intraoperative blood loss, analgesic requirements in the period immediately after surgery, hospitalization times, rate of screw malposition, loss of correction, rate of pseudoarthrosis, and implant mobilization. **Results:** In Group 1 (MIS) the surgery significantly decreased bleeding and there was a lower incidence of malpositioned screws in the recess than in the conventionally-treated group, however the surgery lasted longer. Both groups had similar analgesic requirements, and hospitalization times did not differ significantly. In the long-term, neither group showed any cases of non-union, correction losses, or mobilization of the implants. **Conclusions:** The MIS technique demonstrated longer surgery time and less blood loss, but did not reduce the analgesic requirements or hospitalization times. Initial correction of scoliosis by convexity decreased the incidence of malpositioned screws in the concavity. There was no losses resulting in correction, mobilization of the implants, or non-union.

**Keywords:** Scoliosis/surgery; Adolescent; Spine; Bone screws; Surgical procedures, minimally invasive surgery.

## RESUMO

**Objetivo:** Analisar os resultados de uma nova técnica cirúrgica minimamente invasiva (MIS, de minimally invasive surgery) em abordagem posterior isolada para a correção cirúrgica de escoliose idiopática do adolescente (EIA). **Métodos:** Foram comparados dois grupos de pacientes com EIA Lenke tipo 1A, semelhantes quanto a idade, sexo, ângulo de Cobb, ápice da curva, rotação vertebral, cifose torácica, níveis de fusão, tipo de instrumentação e acompanhamento. Os pacientes do Grupo 1 foram tratados com a técnica minimamente invasiva que será descrita e o Grupo 2, da maneira convencional. Foi analisado tempo de cirurgia, sangramento intraoperatório, necessidade de analgésicos no pós-operatório imediato, estadia hospitalar, taxa de mau posicionamento do parafuso, perda da correção, taxa de pseudoartrose e mobilidade dos implantes. **Resultados:** No Grupo 1 (MIS), a cirurgia diminuiu significativamente o sangramento e houve menor incidência de parafusos mau posicionados no orifício do que no grupo de tratamento convencional, porém o tempo de cirurgia foi maior. Ambos os grupos tiveram necessidade de analgésicos semelhante e o tempo de internação não apresentou diferenças. A longo prazo, em nenhum dos dois grupos houve casos de não-união, perdas de correção nem mobilidade dos implantes. **Conclusões:** A técnica MIS mostrou tempo operatório prolongado e menos perda de sangue, sem reduzir a necessidade de analgésicos nem o tempo de permanência no hospital. A correção inicial da escoliose pela convexidade diminuiu a incidência de parafusos mau posicionados no orifício, não houve perda de correção, mobilidade dos implantes e não-união.

**Descritores:** Escoliose/cirurgia; Adolescente; Coluna vertebral, Parafusos ósseos; Procedimentos cirúrgicos minimamente invasivos.

## RESUMEN

**Objetivo:** Analizar los resultados de una nueva técnica quirúrgica mínimamente invasiva (MIS, por el inglés “minimally invasive surgery”) por vía posterior aislada para la corrección quirúrgica de la escoliosis idiopática del adolescente (EIA). **Métodos:** Se comparan dos grupos de pacientes con EIA tipo 1A de Lenke, similares en cuanto a edad, género, ángulo de Cobb, ápex de la curva, rotación vertebral, cifosis torácica, niveles de fusión, tipo de instrumentación y seguimiento. El Grupo 1 fue tratado con la técnica mínimamente invasiva que describiremos y el Grupo 2, de forma convencional. Se analizaron el tiempo quirúrgico, la pérdida sanguínea intraoperatoria, los requerimientos analgésicos en el postoperatorio inmediato, la estancia hospitalaria, la tasa de mal posición de los tornillos, la pérdida de corrección, la tasa de pseudoartrosis y la movilización de implantes. **Resultados:** En el Grupo 1 (MIS) la cirugía disminuyó significativamente el sangrado y presentó menor número de casos de tornillos mal posicionados en la concavidad que el grupo tratado de forma convencional; sin em-

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bargo la cirugía tuvo mayor duración. Ambos grupos tuvieron requerimientos analgésicos similares y la estancia hospitalaria no presentó diferencias. A largo plazo en ninguno de los dos grupos se encontraron casos de no-unión, pérdidas de corrección, ni movilización de los implantes. Conclusiones: La técnica MIS demostró prolongación del tiempo quirúrgico y menores pérdidas hemáticas, sin disminuir los requerimientos analgésicos ni la estancia hospitalaria. La corrección inicial de la escoliosis por la convexidad disminuyó la incidencia de tornillos mal posicionados en la concavidad, no dio lugar a pérdidas de corrección, movilización de implantes y no-unión.

Descriptores: Escoliosis/cirugía; Adolescente; Columna vertebral; Tornillos óseos; Procedimientos quirúrgicos mínimamente invasivos.

## INTRODUCTION

Conventional posterior approaches to adolescent idiopathic scoliosis require ample muscle exposure and dissection, which is associated with blood loss, wound complications, significant postoperative pain with significant analgesic requirements, and prolonged recovery times.<sup>1-5</sup>

Minimally invasive surgical approaches are increasingly being used in different spinal pathologies with the aim of reducing the morbidity associated with wider approaches.<sup>6-11</sup> These minimally invasive techniques for the treatment of scoliosis via the posterior approach have been used less frequently, and in the case of patients with AIS, their application is more demanding as they involve a greater number of instrumented levels, and the presence of significant spinal rotation hinders the insertion of implants using these techniques.<sup>12</sup> There is also the problem of obtaining adequate fusion, and the difficulty of inserting the rod and of performing corrective maneuvers through small approaches. There are very few publications in the literature on the use of MIS in deformities, and some refer to adult and lumbar scoliosis.<sup>13</sup>

Minimally invasive approaches for the surgical treatment of scoliosis via the posterior approach that have been described are performed using small approaches under radiological control at each level. These approaches claim to involve less surgical aggression and possibly reduce surgical bleeding, analgesic requirements and complications, and could shorten hospitalization times.

In this study, we present a new surgical technique for the minimally invasive treatment of adolescent idiopathic scoliosis via the posterior approach using pedicle screws at all levels. The short- and long-term results are presented, comparing this group of patients with another group with similar characteristics, treated using a conventional approach.

## METHODS

This is a prospective randomized clinical trial comparing two homogeneous groups of 10 patients each with Lenke type 1A AIS, with curves of similar characteristics. One group was treated with the minimally invasive technique discussed here (group 1) and the other conventionally (group 2), all with intraoperative neurophysiological monitoring and radioscopic control (Table 1).

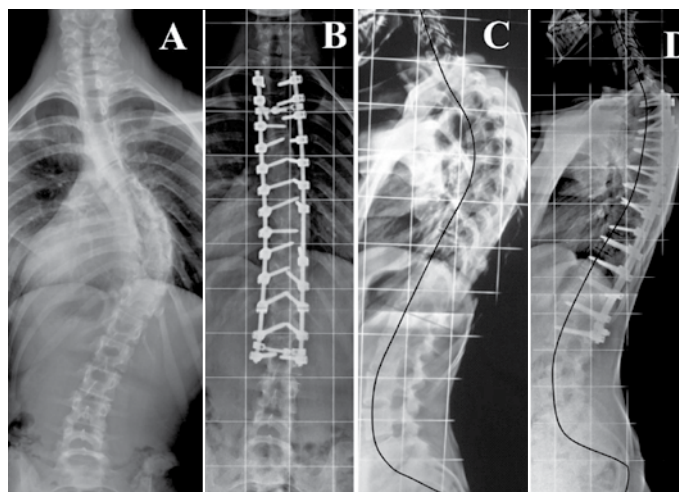
Ten patients (group 1) with Lenke type 1A AIS (Figure 1), average age of 14.3 years (R: 12.1 -16.8) and mean angular value of 60° (R: 53° -71°). In all these cases, the apex was located between T8 and T10, with a mean value of vertebral rotation of 18° Perdriolle (R: 7-23) and mean thoracic kyphosis T5-T12 of +25° (R: 11-40). This group was treated surgically via the posterior approach, performing a minimally invasive approach according to the technique described below. Proximal fusion reached T2 in seven of the patients and T3 in three, and distally L1 in six, and L2 in the remaining four.

Surgical technique for the minimally invasive approach to scoliosis (performed on five fresh cadavers by four of the authors: JIM, JB, EH and CB):

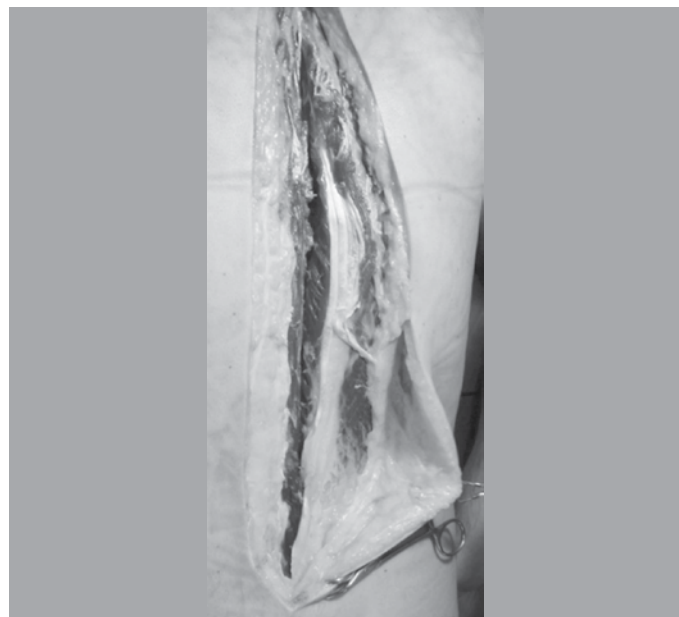
**Table 1.** Preoperative characteristics of the patients.

	Age	Cobb	Apex	Kyphosis T5-T12	Perdriolle
Group 1	14.3 (12.1-16)	60° (53-71°)	T8-T10	+25° (11-40°)	18° (7-23°)
Group 2	15.3 (11-17.4)	56° (45-66°)	T8-T10	+20° (10-36°)	16° (12-32°)

Under general anesthesia, with the patient in the prone position, we made a posterior longitudinal skin incision at the midline that included all the selected levels, dissecting the subcutaneous fascia up to about two centimeters from the midline. A caudal to cephalic opening was made in the thoracolumbar fascia (Figure 2), starting at the lumbar level, using the Wiltse approach, reaching the thoracic level one centimeter from the midline and extracting all the superficial muscles of the back (latissimus dorsi, trapezius, serratus posterior superior and inferior) that are inserted into the posterior layer of the thoracolumbar fascia, accessing the deep musculature (spinalis thoracis and longissimus thoracis).



**Figure 1.** 13-year-old premenarchal girl, diagnosed with Lenke 1AN adolescent idiopathic scoliosis treated via the posterior approach by the minimally invasive technique. (1A and 1B): preoperative and final postoperative tele-x-rays (the latter taken after 27 months of follow-up) (1C and 1D): preoperative and final lateral tele-x-rays.



**Figure 2.** Longitudinal opening of the fascia.

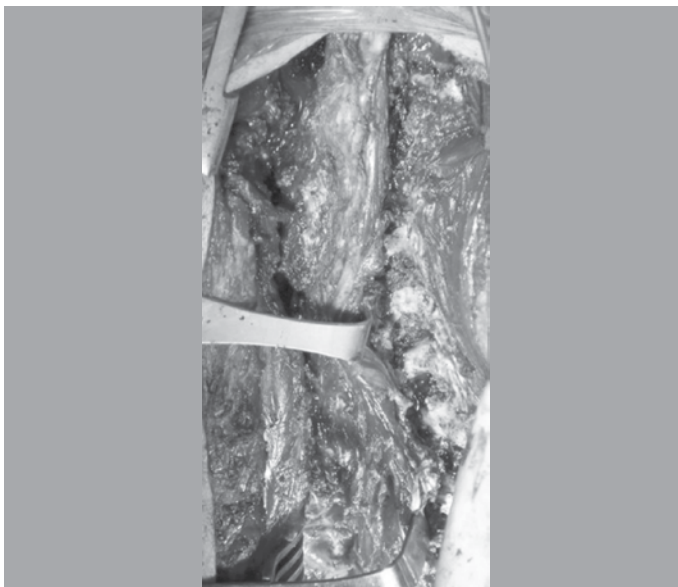
To reach the posterior vertebral elements in the lumbar region, a Wiltse approach is used - making a longitudinal opening three centimeters from the midline in the fibers of the longissimus thoracis (Figure 3) until the lumbar joints can be palpated - and the thoracic spine is accessed via the intermuscular space between the spinalis thoracis and longissimus thoracis until the transverse apophysis can be palpated. Access is the same in the upper thoracic region, with the exception that it is necessary to previously extract the splenius from the neck of the midline.

Once the joints in the lumbar region and the transverse apophysis in the thoracic portion have been clearly identified, primarily by palpation, the joints, transverse apophyses and the pars interarticularis are exposed through periosteal stripping and decortication. This exposed area represents approximately one square centimeter. The thoracic exposure is performed from lower to upper transverse apophysis, and is the process that produces the most bleeding. Sufficient tissue is detached to perform the arthrotomy and view the entry point of the pedicle screw (upper part of transverse apophysis and lateral half of the joint) using the freehand technique. With the arthrotomy, the spine is also flexibilized and arthrodesis is favored at each level.

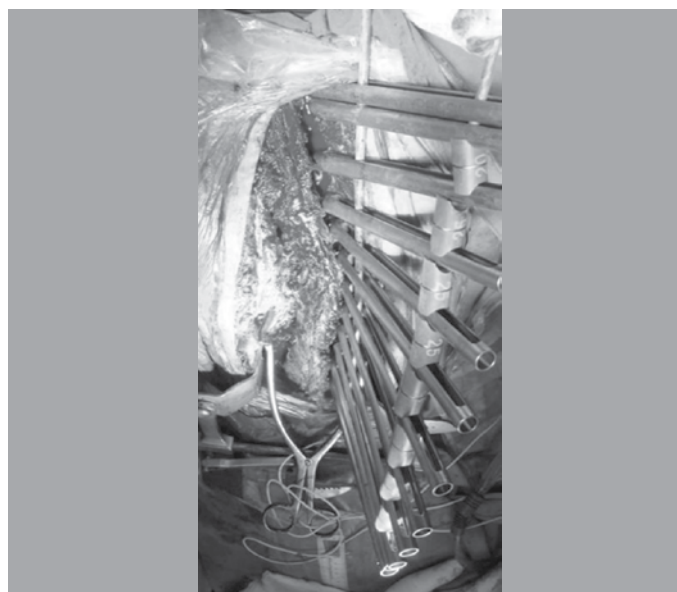
The screws are inserted on the convex side first due to the greater technical ease and less risk of spinal and vascular injury. The pedicles here are wider and more vertical, the spinal cord and major blood vessels are further away, and the screws are positioned using the freehand technique, with correction of the scoliosis using the Coplanar® system (Figure 4) on the convex side.<sup>14</sup>

This stage is followed by placement of the screws on the concave side, also using the freehand technique and the concavity rod (Figure 5) and additional correction maneuvers are used, with hooks if necessary. Finally the Coplanar® (Medtronic) is removed from the convex side and the second permanent rod is placed on the convex side. A local cancellous bone graft is transferred to the Putty bone graft (Bone Grafting Accell Connexus®) in the joints and in the rest of the exposed area, and the surgical wound is closed in planes.

Ten other patients (group 2) also with Lenke type 1A AIS, average age of 15.3 years (R: 11.0-17.4), and angular value of 56° (R: 45-66), all with apex located between T8 and T10, with a mean vertebral rotation value of 16° Perdriolle (R: 12-32) and mean thoracic kyphosis between T5-T12+20° (R: 10-36), underwent surgical correction of scoliosis using a conventional approach and pedicle screws with the freehand technique, fusing proximally in six of the patients up to T2 and in four at T3, and distally up to L1 in seven and up to L2 in the remaining three. The Coplanar® technique was also used in



**Figure 3.** Opening of the longissimus thoracis.



**Figure 4.** Correction using the Coplanar® system.



**Figure 5.** Placement of rod.

this group, but only after all the screws had been inserted, both on the convex and concave sides.

Blood loss, surgery times, analgesic requirements over the first three postoperative days, postoperative complications, the location of the screws on the concave side through postoperative CT scan, postoperative correction, implant failures, number of cases of non-fusion and losses of correction were compared in both groups.

## RESULTS

The mean surgery time of the ten AIS group 1 (MIS) was 6.1 hours (R: 5.1-7.9), while in group 2 (conventional) it was 3.4 hours (R: 2.9-4.7). Intraoperative blood loss in group 1 was 270 cc (R: 220-600) while in group 2 it was 720 cc (R: 450-1160). The analgesic requirements (continuous infusion of tramadol and enantyum) were slightly higher in group 1. The position of the pedicle screws was investigated in the postoperative period using CT scan,<sup>15-20</sup> following the malposition criteria of Kim et al.<sup>21</sup> Of the 101 screws on the concave side of group 1 (all inserted by the same expert surgeon), six screws were found outside the pedicle (6%), two medial

and four external, all of them minimally outside the pedicle and all within the vertebral body. Of the 89 pedicle screws of the concave side of group 2, eleven were not completely contained in the pedicle (12.3%), three medial and eight external, and they were all contained in the vertebral body. Of the screws of the convex side (inserted by less experienced surgeons), 12.6% of the screws of group 1 and 21.6% of those of group 2 were malpositioned, but all of them were included in the vertebral body. The average hospital stay showed no significant differences: 7.6 Days (R:6-10) of average value in group 1, and 7.1 days (6-11) of average value in group 2. (Table 2) No intra- or postoperative complications were recorded in either of the two groups.

After an average follow-up of 39 months (R: 29-41) in group 1 and 35 months (R: 26-39) in group 2, the values for final correction of scoliosis were 81% (R:73-89) and 80% (R:68-96), respectively. (Figure 1) The final T5-T12 thoracic kyphosis had a mean value of 17° (R: 16-26) in group 1 and 22° (R: 15-24) in group 2. No significant losses of correction were found (8% in group 1 and 11% in group 2) and there were no implant failures or cases of non-fusion in either group at the end of the follow-up period.

**Table 2.** Postoperative outcomes.

	Average time	Bleeding	Average stay	Malposition screws concave side	Malposition screws convex side
Group 1	6.1 hours (5.1-7.9)	270 cc (220-600)	7.6 days (6-10)	6% (6/101)	12.6 %
Group 2	3.4 hours (2.9-4.7)	720 cc (450-1160)	7.1 days (6-11)	12.3% (11/89)	21.6 %

## DISCUSSION

The term "minimally invasive" used in this study could be challenged, and perhaps it would be more correct to use "less invasive". But we found the use of "minimally invasive" to be appropriate based on two aspects: firstly, the vertebral bone exposure and muscle detachment are negligible, markedly lower than using the conventional technique, and secondly, our initial strategy was to study the results of a minimally invasive technique carried out with an ample conventional medial longitudinal cutaneous approach, aiming to reduce the initial surgical times of exposure that would certainly be longer if small skin incisions were made. In a second stage, after verifying the satisfactory outcome of the minimally invasive surgical technique with a conventional cutaneous approach, the same technique would be applied using three smaller longitudinal central cutaneous approaches, with the same minimally invasive technique of spinal exposure. Therefore, the technique that we present has only a cutaneous approach that is similar to the conventional technique, but is minimally invasive in the rest of the anatomical structures involved, and this aspect justifies the use of this term.<sup>22</sup>

With the surgical technique that we propose, correcting scoliosis initially on the convex side to facilitate the insertion of the most difficult screws on the concave side by placing them with the curve corrected, the percentage of malpositioned screws on the concave side was lower than on the convex side, even though the pedicles of the concave side are smaller, and the vertebral rotation in scoliosis hinders it, while presenting a greater risk of spinal and vascular injury. Based on these data it would be possible to propose the initial correction of scoliosis on the convex side before inserting the screws on the concave side, which are more difficult and involve a higher risk. This technique would be even more suitable for more severe curves with greater rotation, where the insertion of screws on the concave side becomes more difficult.

Nevertheless, the above data on better location of the pedicle screws on the concave side compared to those on the convex

side may be biased because the surgeon knew beforehand that the location of the screws would be analyzed with CT scan in the postoperative period of the patients submitted to the MIS technique; however, this situation was not raised in the cases of conventional approach, because these patients were chosen at random from a group of surgeries where the study was conducted with postoperative CT to analyze neurophysiological screw monitoring values.

Regarding the recording of comparative intraoperative data on the two groups, our results are similar to those published in the literature, with the use of percutaneous techniques.<sup>23-38</sup>

In our series the minimally invasive technique only decreased the surgical bleeding, but at the cost of a much longer surgery time (almost double that of patients treated using the conventional technique), although this could be partially justified by the learning curve for this technique, as the surgery time declined slightly in the last cases. Therefore, we do not believe that the longer surgery time of minimally invasive approaches should be attributed to the learning curve, but instead, to the slower exposure and the laboriousness of the technique, since it requires more careful and elaborate exposure for the placement of the screws.

A study has been published recently proposing a hybrid approach to the treatment of AIS, one side minimally invasive and the other opened in the conventional manner. The surgeon creates a lateral mini approach to the retroperitoneal approach, and through this approach, performs discectomy and interpositioning of cages filled with bone graft, making a second posterior approach during the same operation, by means of a posterior incision longitudinal to the thoracic levels and mini lumbar incisions for the insertion of pedicle screws and osteotomies, obtaining acceptable clinical and radiographic results. However, its authors recommend a broader comparative study to enable firm conclusions to be drawn.<sup>39</sup>

Another aspect to consider with regard to the minimally invasive technique that we propose is that the arthrodesis achieved in these cases may be less rigid and more elastic, as the fused area is smaller. This fact could reduce the complications associated with the degeneration of the adjacent discs in these patients with a long life expectancy.

A weak point of this study is the low number of patients in whom the minimally invasive technique was used. But at the time this study was designed, one of the questions we raised was whether the much smaller area of arthrodesis in comparison to the conventional technique could give rise to pseudoarthrosis in a significant number of cases, which is why the authors chose a small number of patients. To this effect one of the significant findings of this study, that can be used in the future, is the absence of cases of pseudoarthrosis despite the small arthrodesis surface used, and this aspect of its good long-term results, without complications, supports the development of minimally invasive techniques for the surgical treatment of scoliosis.

In the current situation, with non-specific instrumentations for minimally invasive AIS correction techniques, we cannot recommend this minimally invasive technique based solely on the fact that it involves less surgical bleeding, as it is also associated with a considerable increase in surgery time. Furthermore, no benefit is obtained in analgesia requirements or hospitalization times. We have no doubt that in the near future, the development of specific instruments for the correction of scoliosis with a minimal invasive approach would significantly shorten surgery times, further improving the results in regard to intraoperative bleeding. In this situation, the technique that we propose, or modifications of it, might justify its use.

## CONCLUSIONS

The surgical correction of AIS with the minimally invasive technique compared to the conventional technique reduced surgical bleeding and increased surgery time. It did not change the postoperative analgesic requirements or the average hospitalization time. The initial correction of scoliosis on the convex side through the minimally

invasive approach decreased the incidence of malpositioned screws on the concave side compared to the control group. The minimally invasive technique that we present did not lead to loss of correction or mobilization of the implants and there was not a single case of non-union after a minimum follow-up of 39 months. This situation was similar to that of the group treated conventionally.

At the present time, with non-specific instrumentations for the minimally invasive treatment of scoliosis, we do not consider it justifiable to continue using this minimally invasive technique, as even though it reduced intraoperative blood loss, it significantly increased

the surgery time, without bringing any benefit in terms of analgesia requirements or hospitalization stay.

Nevertheless, its good technical results, good consolidation and the absence of long-term complications leave the door open for the development of minimally invasive techniques for the surgical treatment of scoliosis.

All authors declare no potential conflict of interest concerning this article.

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