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Case Report

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Can Vertebral Pedicular Tethering Preserve Lumbar Motion in the Surgical Treatment of a Lenke 6C Idiopathic Scoliosis? -Technical Note

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Introduction

In the paediatric age group, adolescent idiopathic scoliosis (AIS) is the most common cause of spinal deformity. When the scoliosis progresses beyond 45º of cobb angle, the optimal treatment is surgery with an arthrodesis in order to correct the deformity, stop curve progression and improve spinal balance. Although not ideal, the gold standard surgical treatment of AIS is still fusion of the structural curves but fusing long or short is a matter of the type of scoliosis. According to the Lenke Classification for a type 6C scoliosis, a deformity with a double curve where the major curve is thoracolumbar/lumbar, meaning with a cobb angle larger than in the thoracic curve, if it progresses and reaches an indication for surgery, a long extensive fusion is often required. Occasionally, a restricted number of these cases may be suitable for a shorter selected fusion that means, leaving the thoracic curve out of the arthrodesis but the main thoraco-lumbar or lumbar curve will always require to be fused.

To select the lowest instrumented vertebra (LIV) is to determine the distal end of the fusion. The location of this LIV is crucial because it is highly correlated to the post-op outcome. Inappropriate LIV selection can result in aggravation of the unfused curve, spinal imbalance or distal adding on and may require reoperation [1-3].

Apart from other complications that can arise from getting the wrong LIV in the lumbar spine, we do know that the rates of disc degeneration and pain in the lumbar spine are higher for those patients with lumbar curves that require fusion down to L3 or L4 [4-7].

Although for a Lenke 6C scoliosis the lower instrumented vertebra is usually L3 or L4, the truth is that the ideal LIV for this type of scoliosis is still inconclusive.

In order to prevent these sorts of complications, over the last decades surgeons have been searching for other alternatives, that on one hand would correct the 3D deformity but on the other hand would preserve spinal growth and segmental motion in particular in the lumbar spine. Growth-guiding systems, such as vertebral tethering systems either through the front (Vertebral Body Tethering VBT) or through the back (Vertebral Pedicular Tethering VPT), are on the rise for the management of AIS patients that are younger with some residual growth still expected. These growth modulation techniques aim to maintain mobility and avoid spine fusion if possible. In addition, even though the optimal criteria for the best candidates have yet to be defined, the use of growth guiding systems means that fusion procedures should only be required in patients where the ideal timing for inserting these devices have been missed or where the spinal deformity cannot be adequately addressed using dynamic instrumentations or in a combination of both, as a hybrid system that we present in this case report.

Case Report

This is a 11y old girl, fit and healthy with no menarche. She is very keen on sports and a member of the college football team. Bracing was unsuccessful due to the patient's low compliance claiming that the Boston brace was uncomfortable and hot, as she lives in the southern part of the country where temperatures are usually high throughout the year.

On clinical examination her right shoulder was higher than the left one, waist asymmetry, no leg length discrepancy and spine skin was normal. She presented a full range of motion of all spinal segments and no abnormal neurology on examination. Adams test was positive with a moderate right sided rib hump (scoliometer 10º).

Radiographs that were taken showed a double curve scoliosis – Lenke 6C, lumbar spine with 6 vertebrae and a cobb angle 49,5º and a thoracic cobb angle of 46,9º (Figure 1). As far as growth parameters were concerned she was a Risser 0 and a Sanders 3 (Figure 2). She had a spinal cord MRI that was normal. Bending radiographs were taken and showed a very flexible lumbar curve (Figure 3).

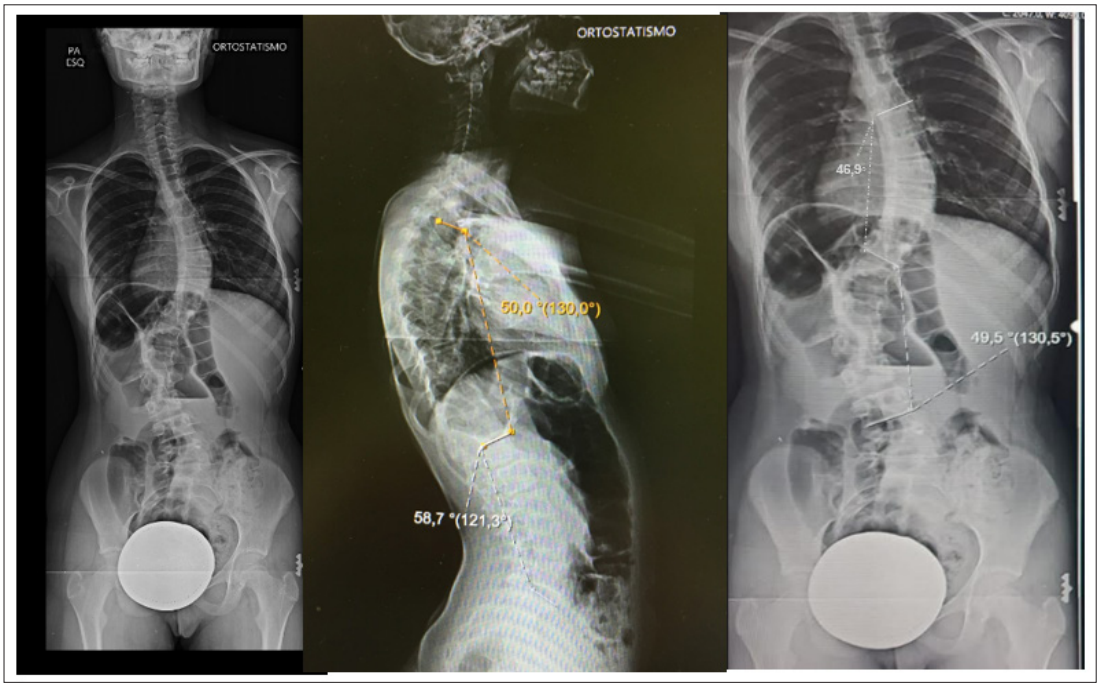

Figure 1: 11y old girl with a Lenke

Figure 2: Skeletal Growth parameters - Sanders 3 and Risser 0

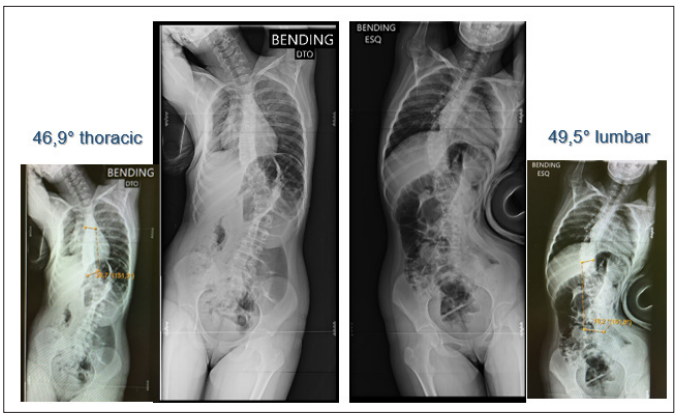

Figure 3: Dynamic Radiographs to test curve flexibility

The two surgical alternatives for treatment were explained and discussed with parents – either a long fusion T4 to L4 or a growth modulation technique preserving the mobility of the lumbar spine but in two stages. First through a Vertebral Pedicular Tethering (VPT) T11 to L4 and wait to see how the thoracic curve would react but if it did not improve, a posterior instrumented fusion of the thoracic spine would be performed at a later stage. Despite the explanation of the pros and cons of each alternative, knowing that there is no mid or long-term follow up for the VPT technique, parents accepted our suggestion and a VPT of the lumbar curve was performed in August 2023 (Figure 4).

Figure 4: Intraoperative supine final radiograph

At 6- and 12-months FU the lumbar curve improved (figure 5 A and B) in both AP and lateral view, but the thoracic curve did not change and the rib hump remained (scoliometer 7º) much the same (height of the rib hump on the lateral spinal radiograph).

Figure 5A: Six months radiograph after VPT procedure to the lumbar curve (standing)

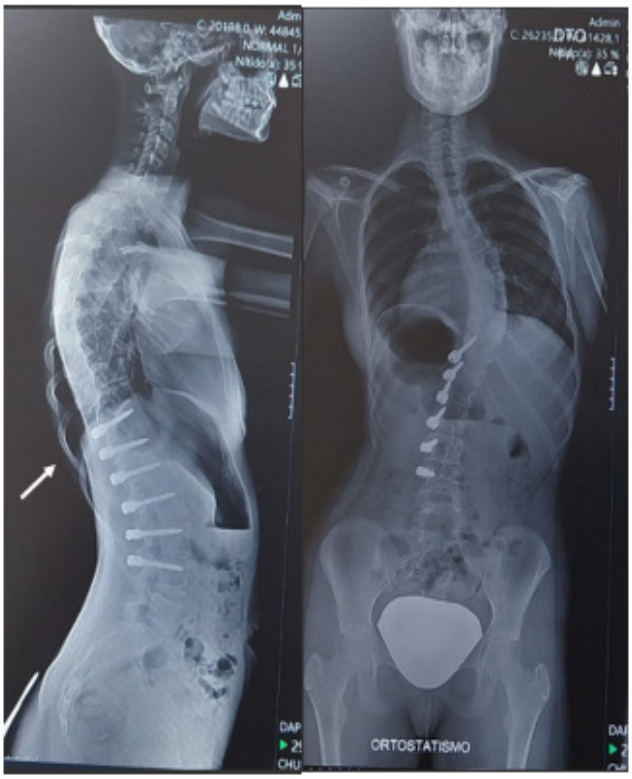

Figure 5B: Twelve months radiograph after VPT procedure to the lumbar curve (standing). Arrow points to the rib hump height on the lateral view

One year later, the girl was 12,5y old and the second stage of the original plan was undertaken with a posterior instrumented fusion from T3 to L2 (figure 6).

Figure 6: Standing Radiograph taken six months after the posterior instrumented fusion to the thoracic spine (18 months after the lumbar VPT)

She made an uneventful recovery and is now back to her normal physical activities. Her lumbar flanks are well balanced and symmetrical and the rib hump height improved from 10 to 3 on the scoliometer.

Latest radiographs do show that functional motion of the lumbar spine is preserved (Figure 7) at 18 months post lumbar VPT.

Figure 7: Lateral Radiograph taken standing in neutral and forward flexion shows the functional motion of the lumbar spine

Discussion

Posterior spinal instrumented fusion is still the gold standard treatment for that adolescent idiopathic scoliosis that failed conservative treatment. However, we do know that on certain occasions, in particular for double structural curves like Lenke 3C and 6C, the arthrodesis required are long, down to the lower lumbar spine either to L3 or L4.

Regardless of the surgical approach used, the main objectives to treat any AIS are to correct the Cobb angle, restore trunk balance in the sagittal and coronal planes, optimize the waist contour and shoulder balance, and correct the rotational malalignment while avoiding complications in the long-term follow-up [8-10]. As a principle, the length of the instrumented fusion should always be as long as necessary to guarantee a stable correction of the 3D deformity and as short as possible to prevent long-term complications from long fusions. However, having a fusion ending too short can result in insufficient correction of the lumbar curve, so that translation of the lumbar vertebrae may not be decreased and the chances of decompensation are higher compromising the final clinical outcome [11,12].

Choosing the correct lower instrumented vertebra (LIV) in these cases is not easy and there is no clear consensus on where to stop and therefore the fusion may not necessarily need to extend to the lowest end vertebra. If a longer fusion can result in better curve correction, a shorter fusion can save more mobile lumbar segments as well as growth potential. According to Wang et al in eight of 25 patients of his series, LIV was at the same level as the lumbar apical vertebra (LAV) [13]. Although this is a shorter fusion, acceptable correction was achieved, but to guarantee satisfactory correction and clinical outcome, they believe it is more reliable to end the fusion below LAV [14].

In a matched-pairs analysis in Koller's series, they were able to show that with a similar Lumbar curve correction, LIV at L3 resulted in a significantly higher rate of Adding ON compared to stopping at L4 and an increased risk of reoperation [15]. Their suggestion is to end the fusion one or two levels below the LAV. Ruffilli et al, pointed out that there is an increased risk of junctional disc degeneration if the fusion ends at L3 or L4 in comparison to fusions ending at L2 [10].

Preserving motion of the lumbar spine is definitely our main concern and therefore lumbar fusions if needed should be as short as possible, but preserving the principles of a successful treatment – correct the 3D deformity with a satisfactory clinical outcome. As we have seen in a Lenke 6C double major structural curves, we would always have to fuse from T2 /T4 down to L4 or eventually L3, compromising motion of this spinal segment. Selective fusions for the Lenke 6C curves mean that a shorter fusion will be performed but at the expenses of the thoracic segment that would be left out but the thoracic spine does not have much motion as we know [16].

If spinal fusion is not the optimal solution for a growing spine, fusing down to L3 or L4 is even more problematic as we have described.

The disadvantages of spinal arthrodesis in this age group of patients have led surgeons to search other surgical techniques for correcting AIS without fusion. To control the asymmetric growth of the vertebral bodies and intervertebral discs, vertebral tethering either through vertebral body (VBT) or pedicles (VPT)

has been introduced as motion preserving alternative to address progressive scoliotic deformities with encouraging results [17,18]. However, the effect of these new constructs on post-operative curve behaviour is not standard and requires larger series and longer follow up in order to be validated.

Vertebral growth modulation procedures are new techniques that have to be performed during the adolescent growth spurt. Spine tethering is one of these techniques, a non-fusion approach that preserves motion and spinal growth, and may guide growth to correct vertebral deformity in the adolescent, therefore more likely to succeed only if performed in certain phases of the growth spurt that have not yet been fully identified (probably Sanders 3 or 4).

Based on the evidence from our small series of Lenke 5C scoliosis treated with VPT, there is an spontaneous progressive improvement in the thoracic vertebral apical rotation and improvement of the thoracic rib hump with spinal growth [17]. Based on this finding we decided in this girl not to address the solution for the lumbar curve at the same time as for the thoracic curve. We planned to perform both procedures staged, expecting some of the thoracic vertebral derotation to improve with the gradual correction of the lumbar curve with VPT. As all posterior pedicular compressive instrumentation, VPT has an associated potential to induce lordosis and therefore would not be suitable to use in the thoracic scoliosis, so the alternative to reconstruct a thoracic kyphosis and derotate the apical vertebrae would have to be with a posterior spinal instrumented fusion but in this case we wanted to make sure there was no "free" disc between the rigid and the mobile instrumentation and therefore the two instrumentations would have to overlap over a segment as shown in figure 6 – mobile instrumentation ends in T11 and rigid instrumented fusion ends at L2.

Could we have stopped at L1? Probably, but the behaviour of this transitional segment is something we need to look into more accurately in the future in order to keep it as short as possible and as long as necessary to avoid mechanical complications in this transitional area.

Could we have done the two operations at the single index procedure? Yes indeed, but knowing that compensatory thoracic curves do improve with thoracolumbar/lumbar (TL/L) cobb angle correction with VPT, we thought it was worth trying although in the dynamic view it did not reach 25º [17,19]. In the future as long as the TL/L curve fulfils the criteria for VPT – cobb angle between 40º and 60º and a 50% flexibility in a patient with a Sanders 3 or 4 - and it is a Lenke 6C with no indication for a selective fusion we will perform both procedures at the same time.

What is the more likely complication in such a procedure in growing spine? from our previous series there are chances of overcorrection of the coronal deformity but this is more likely to happen up to two years post op [17,19]. The other theoretical complication that could happen is hyperlordosis on the same segment but this has never been noticed in our patients. Both these mechanical complications are simple to solve as pointed out in our original article, by cutting the tether at two or three levels under local anaesthetic through the same midline incision [17].

In a recent series published by Eaker et al with 27 patients with Lenke 5 and 6 (10 patients withLenke 6) scoliosis treated with anterior Vertebral Body Tethering (VBT),TL major curvature treated with this anterior approach experienced a high rate of clinically successful outcomes (89% of patients with a major lumbar curve <35º) with maintenance of lumbar lordosis although with a 10,8% of major complications and a high rate of tether breakage no matter if one or two cords were used [20]. Flexibility of the thoracic curve was not taken into account for decision making in this series of patients with a minimum of 2y FU. Correlation between tether breakage rate and curve flexibility or Sanders Skeletal staging was not described.

When we talk about spinal growth modulation techniques through spine tethering for correction of an AIS we should look at the results of the procedure performed from an anterior (VBT) or a posterior approach (VPT). If we look at our series of patients at six and twelve months FU with good radiographic and clinical results, with a low minor complication rate (two cases of overcorrection in 12 patients) and no cases of tether breakage identified and we compare with the results and complication rate of Eaker's series(20) it makes you wonder if, for achieving similar good results a major undertaking (opening from the front the chest, the diaphragm and the abdomen) with severe complications in a growing child with a scoliosis, is justified [16,18].

In this case report, we have achieved a well-balanced spine and a good clinical outcome with a hybrid construct that we believe will be a good solution for these severe Lenke 6C scoliosis, avoiding an arthrodesis to L4 and therefore preserving functional motion of the lumbar spine in a 13y old active girl that has not yet achieved the end of growth.

Conclusion

Spinal Growth Modulation sounds a promising technique that has been used successfully for the treatment of certain adolescent idiopathic scoliosis. It cannot be the panacea for all thoraco-lumbar or lumbar scoliosis because we need to operate on these patients at the "certain" stage of the adolescent growth spurt but the exact timing is still difficult to identify. For these adolescents, Sanders 3 or 4, seems to be the best phase to perform the thoracolumbar/lumbar VPT and major double curves that have to undergo surgery, an hybrid solution should be taken into account as an alternative preserving not only motion in the lumbar spine but also spinal growth. We present a 11y old girl that was successfully treated operatively with a vertebral pedicular tethering in the thoracolumbar curve and a posterior spinal instrumented fusion in the thoracic curve.

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