The Left Bending Stable Vertebra; A Method for Determining the Lower Instrumented Vertebra in Single Thoracic (Lenke IA and IB) Adolescent Idiopathic Scoliosis

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Abstract

Background Data: The selection of the lower instrumented vertebra (LIV) in single thoracic (Lenke1A and B) Adolescent Idiopathic Scoliosis (AIS) remains controversial.

Purpose: To report a new method of selecting the LIV and report the results of surgery based upon this method.

Study Design: Retrospective radiological analysis of Lenke 1A and B AIS patients.

Patients and Methods: Fifty six patients met the inclusion criteria, 4 (7.1%) male and 52 (92.9%) females. Mean age at time of surgery was 14.7 years. The following data were recorded on preoperative, immediate postoperative and latest follow up x-rays: the lower end vertebra (EV), the stable vertebra (SV), the neutral vertebra (NV), the vertebra most closely bisected by a central sacral perpendicular line that was designated the left bending stable vertebra (LBSV) and the lower instrumented vertebra (LIV). Patients were checked for coronal balance and the development of adding on the latest follow up X-rays.

Results: Patients were followed up for a mean of 28.5 months. Mean thoracic curve correction was 69%. Five patients (9%) developed adding on at their latest follow up. All patients instrumented at or distal to the LBSV were balanced without adding on. Five out of the six patients (83%) instrumented proximal to the LBSV developed adding on at their latest follow up.

Conclusion: The LBSV is a useful and reliable way of determining the LIV in Lenke 1A and B AIS. Both the LBSV and Suk et al method predicted adding on; however, the LBSV can allow a more proximal LIV and therefore a shorter fusion in up to 46% of this case series. (2012ESJ022)

Keywords: single thoracic idiopathic scoliosis, left bending stable vertebra, fusion level, lower instrumented vertebra, Lenke I, pedicle screw fixation.

Introduction

The aim of fusion in idiopathic scoliosis is to achieve a balanced spine with the shortest fusion preserving motion segments particularly in the lumbar spine[1]. Pedicle screw fixation enables enhanced three-dimensional correction of spinal deformities and effectively shortens the extent of fusion. However, the choice of distal fusion level is still controversial in single thoracic idiopathic scoliosis with the lumbar compensatory curve not crossing the middle line (Lenke type 1 with modifier A or B, King type III and IV curves)[6,7].

Some authors have suggested that fusion should extend to two vertebrae below the end vertebra as a general guide[6]. Others have stressed the necessity of fusion from the superior neutrally rotated vertebra to the inferior neutrally rotated vertebra[3].

Moe et al stressed the importance of analysis of levels of rotation, as well as the use of preoperative supine side-bending roentgenograms to determine the degree of a flexible lumbar curve, and have advocated fusion of the thoracic curve from the superior neutrally rotated vertebra to the inferior neutrally rotated vertebra[5]. Lenke et al suggested that the lower instrumented vertebra (LIV) should be either the stable or one and occasionally two levels above the stable vertebra distally. Their most common LIV was the “stable minus one” (SV-1) lumbar vertebra[4].

Some authors consider the rotation of the lumbar vertebra just below the lower thoracic end vertebra an important landmark in determining the lower limit of the fusion [6]. Suk et al have outlined a method depending upon the neutral vertebra and its relationship to the lower end vertebra[8]. Evaluation of the lateral bending radiograph is one of the most common methods currently used for the preoperative assessment of spinal flexibility[9].

The purpose of this study is to report a new method for determining the lower instrumented vertebra in single thoracic adolescent idiopathic scoliosis (AIS) (Lenke 1A and B), based upon the assessment of the left bending films and to assess the results of surgery based on this new method.

Patients and Methods

The clinical charts and radiographs of patients operated upon by the author for Lenke IA and IB adolescent idiopathic scoliosis at Cairo University Hospitals, Egypt, the Spinal Unit Nasser Institute, Cairo, Egypt and AOA Neuro-spinal Centre, Tripoli, Libya from January 2004 to September 2008 were reviewed**.**

To be included in the series, a patient had to have been eighteen years old or younger at the time of surgery, and a preoperative standing antero-posterior and lateral roentgenogram and a complete set of preoperative supine side-bending roentgenograms had to be available. All patients underwent posterior spinal fusion with segmental pedicle screw instrumentation, and had to have a minimum follow up of 24 months.

A total of 56 patients, 4 (7.1 %) male and 52 (92. 9 %) female, met these criteria. They ranged in age from ten to eighteen years (mean 14.7 years) at the time of surgery. The length of follow-up ranged from 26 to 48 months, with a mean of 28.5 months.

The levels of fusion and instrumentation were recorded from the charts and radiographs. The radiographs were reviewed using the Cobb method, paying particular attention to the stable vertebra. The stable vertebra (SV) was determined as the most proximal lumbar vertebra most closely bisected by the central sacral vertical line (CSVL) [9] (line drawn through the center of the sacrum perpendicular to the iliac crests).

Lateral-bending radiographs were made with the patient lying supine and asked to bend sideways as much as he/she can (voluntary side bending). The most proximal vertebra, at or distal to the end vertebra, bisected by central sacral perpendicular line on the supine left bending view was designated the left bending stable vertebra (LBSV). In left bending film, the central sacral line is perpendicular to the plane of the pelvis (Figure 1).

The following data were recorded on the preoperative films, immediate postoperative and the latest follow up x-rays including: the lower end vertebra (LEV), the stable vertebra (SV), the neutral vertebra (NV), the left bending stable vertebra (LBSV), and the lower instrumented vertebra (LIV). The presence of coronal imbalance or the development of adding on was checked on the immediate postoperative & at the latest follow up films.

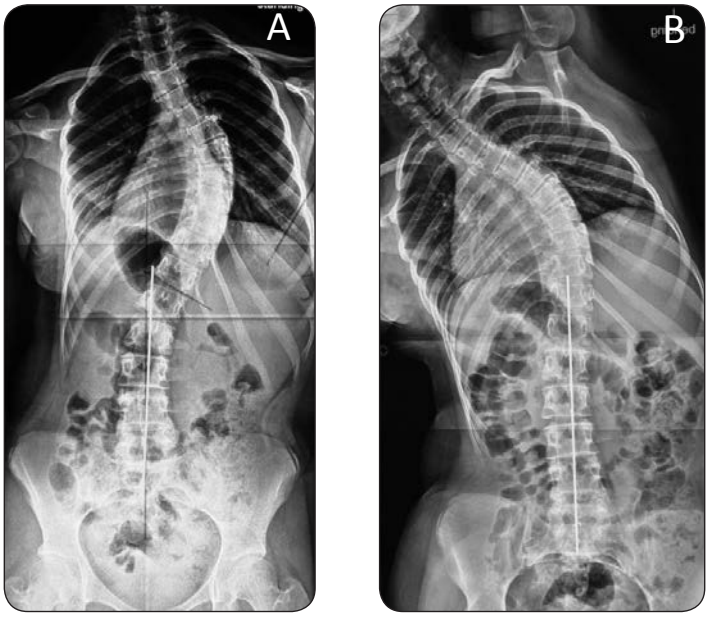

Figure 1.
A: standing full length spine x-ray with the central sacral vertical line drawn. The lower end vertebra (EV) is T12, the stable vertebra (SV)is L2, and the neutral vertebra (NV) is L3.
B: the left bending x-ray with the central sacral perpendicular line to the plane of the pelvis drawn. The left bending stable vertebra (LBSV) is the most cranial vertebra at or distal to the end vertebra best bisected by the drawn line: in this case T12.

Results

Patients were followed up for 26-48 months (mean 28.5 months). Preoperative 45°-87° (mean 66°) of thoracic frontal plane deformity was corrected to 7°-23° (mean 15°) at the immediate postoperative films. The corrected curves lost 1°-5° degrees (mean 3.1°) at final follow up, and the mean correction rate of the thoracic curve was 69% at the final follow-up. All patients were in coronal balance at their immediate postoperative films.

Five patients (9%) developed adding-on in their latest radiographs. Adding-on is defined as progressive tilting or displacement of vertebra/e distal to the instrumentation to be included within the main thoracic curve[10].

The Relationship between the lower instrumented vertebra (LIV), the end vertebra (EV), the stable vertebra (SV) and left bending stable vertebra (LBSV) was studied (Table 1). All patients that had their LIV at or distal to the LBSV were balanced without adding on. Five out of the six patients (83%) who had their LIV proximal to the LBSV developed adding on at the latest follow up (Table 2) (Figures 2, 3).

Other complications included: one case of infection in a diabetic 17 year old girl that required debridement and another that required a wound swab and extended IV antibiotics for 10 days. Both patients' infection cleared up. There were no neurological or implant related complications.

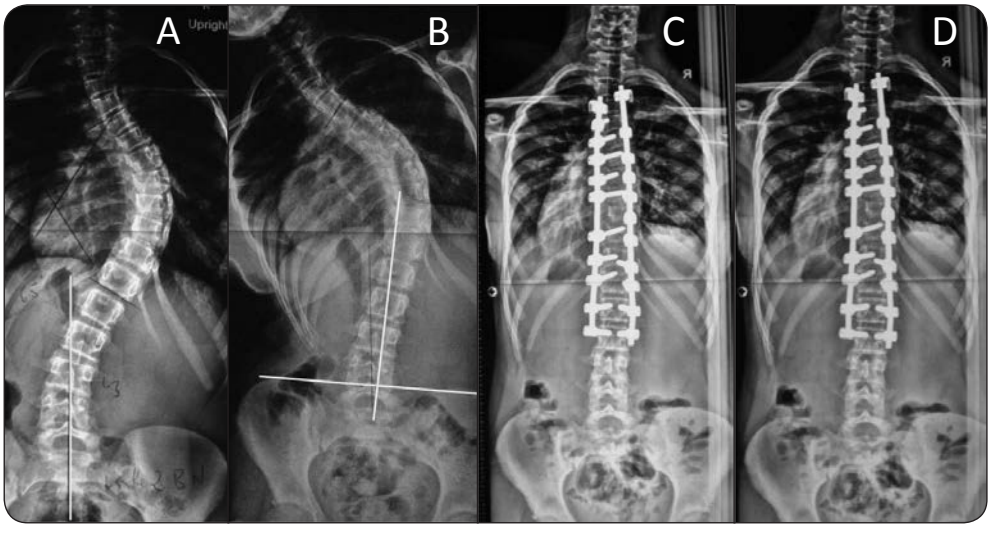

Figure 2.
A: full length standing x-ray, EV T12, SV L3 and NV L2.
B: the left bending film showing LBSV at L1**.**
C: 2 weeks postop standing x-ray showing a well balanced spine, LIV selected at L2 (LBSV+1).
D: 32 months postop standing x-ray showing a well balanced spine with no adding on.

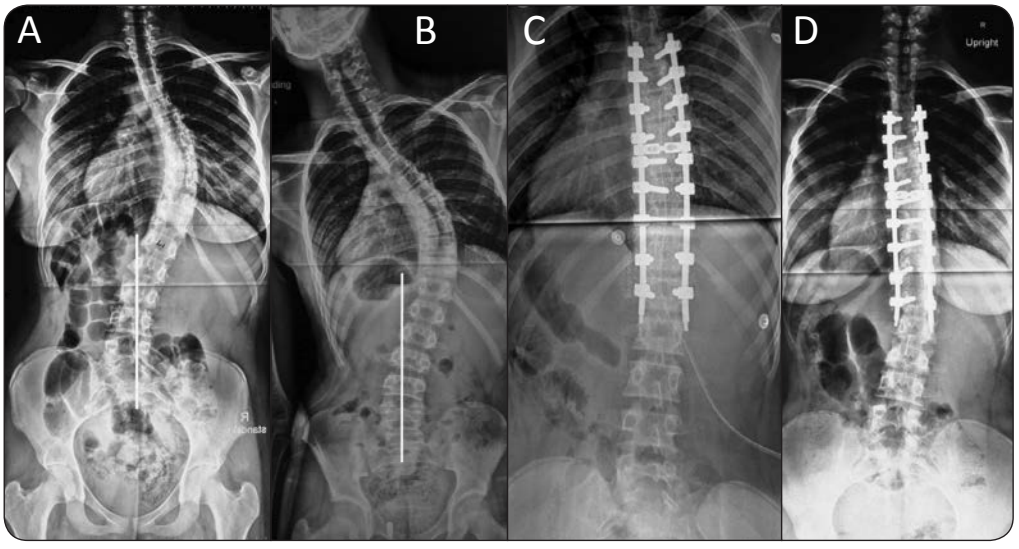

Figure 3.
A: standing x-ray showing EV L1, SV L3, NV L3.
B: left bending x-ray showing LBSV at L3. **C:** immediate postop standing x-ray showing a well balanced spine. LIV at L1 (LBSV-2).
D: 28 months postop x-ray showing development of adding on.

Table 1. The position of the Left Bending Stable Vertebra (LBSV), the End Vertebra (EV) and the Lower Instrumented Vertebra (LIV) in relation to the Stable Vertebra (SV).

	LBSV	EV	LIV
SV	14(25%)	0(0%)	6(11%)
SV-1	16(29%)	9 (15%)	24(43%)
SV-2	22(39%)	35(63%)	20(35%)
SV-3	4(7%)	12(22%)	6(11%)

Table 2. Postoperative Adding on According to the Relationship between the LBSV and the LIV.

	LIV	Adding On
LBSV-2	3	3/3
LBSV-1	3	2/3
LBSV	42	0/42
LBSV+1	6	0/6
LBSV+2	2	0/2

Discussion

The primary goal of surgical treatment in adolescent idiopathic scoliosis (AIS) remains the arrest of further curve progression by obtaining a solid arthrodesis mass and long-term balance of the spine both in the sagittal and coronal planes, with preservation of the maximum number of motion segments[1,5].

With the introduction of more powerful instrumentation systems for the correction of scoliosis, such as segmental pedicle screws, there has been a growing interest in reducing the number of levels fused for the correction of the single thoracic curve while maintaining mobile lumbar motion segments. However the reduction of fusion extent can be complicated by postoperative decompensation and ‘‘adding-on’’ of compensatory lumbar curves[2,8,10].

King et al., recommendations for distal fusion were based on Harrington instrumentation, so not suitable for all pedicle screw constructs[3]. Lenke et al., recommended that one can instrument at or one vertebra proximal to the stable vertebra, without outlining a clear method for determining the LIV[4]. By comparing the relative position of the LBSV and SV, we found that the LBSV was two or three vertebrae proximal to the SV in 26/56 (46%) of our cases (Table 1). This simply means that using our method can allow a shorter fusion in up to 46% of our cases compared to the Lenke et al., recommendations.

Suk et al., showed the importance of the relationship of LIV and the NV. Their method depends upon the relationship between the end vertebra (EV) and the neutral vertebra (NV). When the NV and EV were within two vertebrae apart, they recommended fusion to the NV. When the NV and EV were more than two vertebrae apart,

they recommended fusion down to one vertebra proximal to the NV (NV-1)[8]. We have applied this method to our patients and found it to be indeed predictable of adding on (Tables 3, 4). To compare our method with the Suk et al., one, we compared the position of the LBSV to the NV. We found that the LBSV was two or more vertebrae proximal to the NV in 24/56 patients (43%). This position would be unacceptable according to Suk et al. This simply means that while both methods predicted adding on in this series, using the LBSV method can allow a more proximal LIV and therefore a shorter fusion in 43% of our patients (Table 5).

Table3. Group one (NV two vertebrae or less distal to EV) 18 patients. According to Suk et al, the LIV should be the NV.

	LIV	Adding on
NV+2	3	0/3
NV+1	5	0/5
NV	5	0/5
NV-1	5	1/5

Table 4. Group two (NV more than two vertebra distal to EV) 38 patients. According to Suk et al, the LIV should be the NV-1.

	LIV	Adding on
NV	0	0/0
NV-1	4	0/4
NV-2	10	1/10
NV-3	15	2/15
NV-4	9	1/9

Table 5. Relationship between the neutral vertebra (NV) & the left bending stable vertebra (LBSV).

	LBSV
NV-3	17
NV-2	7
NV-1	12
NV	9
NV+1	9
NV+2	2

Conclusions

The left bending stable vertebra (LBSV) can be used to determine the lower instrumented vertebra in Lenke IA and IB AIS. Instrumenting at or distal to LBSV was associated with a balanced spine and lack of development of adding on at the latest follow up. Eighty three percent of those instrumented proximal to the LBSV developed adding on.

References

1. Bridwell KH: Surgical treatment of idiopathic adolescent scoliosis. Spine 24:2607–2616, 1999
2. Kim YJ, Lenke LG, Cho SK, Bridwell KH, Sides B, Blanke K: Comparative analysis of pedicle screw versus hook instrumentation in posterior spinal fusion of adolescent idiopathic scoliosis. Spine 29:2040–2048, 2004
3. King HA, Moe JH, Bradford DS, Winter RB: The selection of fusion levels in thoracic idiopathic scoliosis. J Bone Joint Surg Am 65:1302-1313, 1983
4. Lenke LG, Betz RR, Haher TR, Lapp MA, Merola AA, Harms J, Shufflebarger HL: Multisurgeon assessment of surgical decision-making in adolescent idiopathic scoliosis: curve classification, operative approach, and fusion levels. Spine 26(21):2347-53, 2001
5. Moe, JH, Winter RB, Bradford DS, Lonstein JE: Moe's Textbook of Scoliosis and Other Spinal Deformities. Philadelphia. WB Saunders, 2nd ed, 1978
6. Parisini M. Di Silvestre F. Lolli G. Bakaloudis P: Selective thoracic surgery in the Lenke type 1A: King III and King IV type curves. Eur Spine J 18 (Suppl 1):S82–S88, 2009
7. Suk S, Lee S, Chung E, Kim J, Kim S: Selective thoracic fusion with segmental pedicle screw fixation in the treatment of thoracic idiopathic scoliosis: more than 5-year follow-up. Spine 30:1602–1609, 2005
8. Suk S, Lee S, Chung E, Kim J, Kim W, Sohn H: Determination of distal fusion level with segmental pedicle screw fixation in single thoracic idiopathic scoliosis in type III and IV curves. Spine 28:484–491, 2003
9. Vaughan JJ, Winter RB, Lonstein JE: Comparison of the use of supine bending and traction radiographs in the selection of the fusion area in adolescent idiopathic scoliosis. Spine 21(21):2469-73, 1996
10. Wang Y, Hansen ES, Hoy K, Wu C, Bünger CE: Distal adding-on phenomenon in Lenke 1A scoliosis: risk factor identification and treatment strategy comparison. Spine 36(14):1113-22, 2011

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الملخص العربي

الفقرة المستقرة في الانحناء الأيسر؛ طريقة لتحديد الفقرة السفلى المثبتة في الجنف الصدري (IB,IA Lenke) مجهول السبب لدى المراهقين.

بيانات أساسية: اختيار الفقرة السفلى المثبتة في الجنف الصدري (IB,IA Lenke) مجهول السبب لدى المراهقين (AIS) لا تزال مثيرة للجدل.

الغرض: أن أقدم طريقة جديدة لاختيار الفقرة السفلى المثبتة وتقديم تقرير عن نتائج الجراحة على أساس هذا الأسلوب.

تصميم الدراسة: تحليل بأثر رجعي لأشعات مرضى الجنف الصدري (IB,IA Lenke) مجهول السبب لدى المراهقين.

المواد والأساليب: ٥٦ مريضا اجتازوا معايير الاشتمال، ٤ (٧,١٪) من الذكور و٥٢ (٩٢,٩٪) إناث. وكان متوسط العمر في وقت الجراحة ١٤,٧ عاما. وسجلت البيانات التالية على أشعات ما قبل الجراحة، وبعد الجراحة مباشرة والمتابعة الأخيرة : فقرة نهاية الجنف السفلى (EV)، والفقرة المستقرة (SV)، والفقرة المحايدة (NV)، والفقرة المستقرة في الانحناء الأيسر (LBSV) والفقرة السفلى المثبتة (LIV). تم فحص المرضى لتحقيق التوازن الإكلينيكى ومتابعة حدوث إضافة في الانحناء.

النتائج: تمت متابعة المرضى لمدة ٢٨,٥ شهرا في المتوسط . كان نسبة تصحيح المنحنى الصدري ٦٩٪. خمسة مرضى (٩٪) أظهروا إضافة على الانحناء أسفل التثبيت في أحدث المتابعات. جميع المرضى الذين تم تثبيتهم حتى الفقرة المستقرة في الانحناء الأيسر (LBSV) أو أسفل من ذلك حققوا توازنا في المتابعة الأخيرة. ٨٣٪ من المرضي الذين تم تثبيتهم أعلى من الفقرة المستقرة في الانحناء الأيسر أظهروا إضافة على الانحناء في المتابعة الأخيرة.

مناقشة: موقف الفقرة المستقرة في الانحناء الأيسر (LBSV) كان فقرتين أو أكثر أعلى من الفقرة الثابتة (SV) في ٤٣٪ من الحالات. تطبيق طريقة سوك لهذا الفوج من المرضى توقع حدوث إضافة في الانحناء بشكل صحيح. ومع ذلك، كانت الفقرة المستقرة في الانحناء الأيسر (LBSV) فقرين أو أكثر أعلى من الفقرة المحايدة (NV) في ٤٦٪ من الحالات.

الخلاصة: الفقرة المستقرة في الانحناء الأيسر (LBSV) هو وسيلة مفيدة وموثوقة لتحديد الفقرة السفلى للتثبيت في الجنف الصدري (IB,IA Lenke) مجهول السبب لدى المراهقين. وقد تنجح هذه الطريقة في تحقيق تثبيت أقصر بالمقارنة بطريقة سوك.