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In-vivo demonstration of the effectiveness of thoracoscopic anterior release using the fulcrum-bending radiograph: a report of five cases

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Abstract Thoracoscopic anterior release of stiff scoliotic curves is favored because of its minimally invasive nature. Animal and human cadaveric studies have shown that it can effectively improve spinal flexibility in non-scoliotic spines; however it has not been demonstrated to be effective in actual patients with scoliosis. The fulcrum-bending radiograph has been shown to accurately reflect the post-operative correction. To demonstrate that the flexibility was increased after the anterior release; five patients with idiopathic thoracic scoliosis who underwent staged anterior thoracoscopic release and posterior spinal fusion were assessed using the fulcrum-bending radiograph. The average number of discs excised was four. Spinal flexibility as revealed by the fulcrum-bending technique, was compared before and after the anterior release. The patients were followed for an average of 4 years (range 2.2–4.9 years). Fulcrum-

bending flexibility was increased from 39% before the thoracoscopic anterior spinal release to 54% after the release ($P < 0.05$). The average Cobb angle before the anterior release was 71° on the standing radiograph and 43° with the fulcrum-bending radiograph. This reduced to 33° on the fulcrum-bending radiograph after the release, and highly corresponded to the 30° measured at the post-operative standing radiograph and at the latest follow-up. Previous animal and cadaveric studies demonstrating the effectiveness of thoracoscopic anterior release did not have scoliosis. We are able to demonstrate in patients with adolescent idiopathic scoliosis, that thoracoscopic anterior spinal release effectively improves the spinal flexibility.

Keywords Adolescent idiopathic scoliosis · Video-assisted thoracoscopic surgery · Thoracoscopy · Spinal flexibility · Anterior release

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Introduction

In the management of patients with stiff thoracic scoliosis and kyphosis, anterior spinal release is helpful in increasing the spinal flexibility and therefore, the result of deformity correction. Excision of intervertebral discs through open thoracotomy is the preferred method in the past. However, cutting of the chest-wall muscles is associated with complications such as reduced ventila-

tion, post-operative atelectasis, extensive and painful scars, blood loss, and prolonged hospital stay [7].

Video-assisted thoracoscopic surgery (VATS) for anterior release of the spine is becoming increasingly more popular due to its minimally invasive nature [1, 19, 25]. However, opponents do not believe that VATS is effective in improving the spinal flexibility as it is difficult to perform a radical discectomy, and to a lesser extent, rib-head excision by thoracoscopy [5, 23]. While VATS

supporters have used animals and cadavers to demonstrate the effectiveness of thoracoscopic spinal release [6, 20], these studies were performed in spines that did not have scoliosis.

The fulcrum-bending radiograph, obtained with the patient lying sideways hinging over a fulcrum provides a simple and reproducible technique for the in-vivo assessment of spinal flexibility. It can accurately predict before surgery, the amount of correction that can be achieved by modern segmental spinal instrumentations [4, 11, 16, 17]. Using this method, one can assess the effectiveness of an anterior release by either directly comparing the spinal flexibility (as reviewed by the fulcrum-bending radiograph) before and after an anterior release, or indirectly by comparing the predicted correction by the pre-release fulcrum-bending radiograph and the actual correction achieved by the anterior release and posterior fusion. Either way, differences in the measured Cobb angle would be attributable to the effect of the thoracoscopic release.

In our institution, a number of thoracoscopic anterior release and posterior fusion surgeries for thoracic idiopathic scoliosis were staged. This gave the opportunity to perform the fulcrum-bending radiograph before and after the anterior release, thereby allowing direct assessments of flexibility changes as a result of the thoracoscopic procedure.

Materials and methods

Between 1997 and 1999, five patients with idiopathic scoliosis requiring anterior release for stiff thoracic curves were prospectively investigated. The authors define stiff curves as those which have a Cobb angle of more than 40° with the fulcrum-bending radiograph; this was arbitrarily used as we felt that the residual curves of over 40° gave unacceptable cosmetic results, and therefore a flexibility-modifying procedure would be indicated. The mean age at the time of operation was 23.0 years (range 13.9–35.3). According to the King's classification [10], there were one type I, two type II, and two type III curves. For the patient with type I curve, both thoracic and lumbar curves were corrected and fused, and for the type II and III curves, only the thoracic curves were instrumented. According to Lenke's classification [12], there were three type I, one type III, and one type V curve.

All the patients underwent an anterior thoracoscopic release, followed by a second-stage posterior instrumented correction, and fusion 1 week later. The instrumentations used for the posterior spinal fusion were Texas Scottish Rite Hospital (TSRH, $n=2$; Sofamor-Danek, Memphis, TN, USA), ISOLA ($n=2$; Acromed Corp., Cleveland, OH, USA), and CD-Horizon (CD-H: $n=1$; Sofamor-Danek, Memphis, TN, USA) systems.

The mean number of thoracic discs resected was four, ranging from 3 to 5 (Table 1). Posterior fixation was done by a pre-dominant hook construct using one upper and two intermediate hooks, and either a hook or pedicle-screw at the lowest fusion level.

The thoracoscopic anterior release was performed with the patient under general anesthesia. The technique involved a discectomy by making a large annular window over the convex side of the scoliosis; the whole nucleus and cartilaginous end-plates were removed. Excision of the posterior annulus to the posterior longitudinal ligament is always attempted but is usually successful only at the apical discs. Rib-head excision was not performed.

The effectiveness of the thoracoscopic anterior release in increasing spinal flexibility was investigated by two methods. First by a direct comparison of the Cobb angle measured from a pre-release fulcrum-bending radiograph with that of the post-release fulcrum-bending radiograph. Second, by an indirect method, comparing the pre-release fulcrum-bending radiograph with the final post-operative correction. As the pre-operative fulcrum-bending radiograph has been reported to be able to accurately predict the post-operative coronal deformity correction for posterior surgery [4, 11, 17], the difference of the Cobb angles between the pre-operative fulcrum-bending radiograph (which predicted the correction for the posterior surgery alone) and the post-operative standing X-ray (which shows the actual correction achieved by combined anterior release and posterior instrumentation) will indirectly demonstrate the in vivo effect of the anterior thoracoscopic spinal release. Statistical analyses were carried out using the Student's *t*-test, with a significance level of ($P < 0.05$).

The "fulcrum flexibility", a measure of the spinal flexibility as revealed by the fulcrum-bending radiograph [11, 17] was calculated based on the following formula:

$$\text{Fulcrum flexibility (\%)} = \frac{\text{Preop Cobb angle} - \text{FB Cobb angle}}{\text{Preop Cobb angle}} \times 100$$

where FB stands for fulcrum bending.

This relationship was used to directly assess the changes in flexibility as a result of the anterior release.

Results

The patients were followed for an average of 4 years (range 2.2–4.9 years). The mean fulcrum flexibility before the anterior release was 39%; it increased by 15–54% after the anterior thoracoscopic release ($P < 0.05$).

The mean pre-operative Cobb angle on the postero-anterior (PA) standing radiograph was 71°, the mean

Table 1 General patient data

	Case 1	Case 2	Case 3	Case 4	Case 5
King's type	II	II	III	III	I
Age (years) at operation	21.5	13.9	25.4	35.2	19.1
Levels released	T7-T10	T7-T11	T6-T10	T7-T12	T6-T10
Number of discs released	3	4	4	5	4
Instrumentation used	TSRH	TSRH	ISOLA	CD	ISOLA

pre-operative fulcrum-bending angle was 43°, the mean post-release fulcrum-bending angle was 33°, and the actual mean Cobb angle after combined anterior thoracoscopic release and posterior surgery was 30°. The latter correlated with the post-release fulcrum-bending result ($P=0.09$), and was significantly different ($P<0.05$) from the pre-release fulcrum-bending result to suggest that the thoracoscopic anterior release can effectively improve the surgical correction of the coronal curve. On an average, four discs were excised per patient, and as the mean improvement in correction is 13°, it suggested that resection of one disc resulted in a mean improvement in correction by approximately 3° (Table 2, Fig. 1).

The immediate post-operative Cobb angle of 30° (data not shown) was well predicted by the post-release fulcrum-bending radiograph of 33°. There was no significant change in this correction at the latest follow-up (Table 2).

Discussion

Anterior spinal release by open thoracotomy has been extensively used in the past to help improve spinal flexibility in stiff thoracic scoliosis. Its role has been increasingly taken over by VATS as the latter is associated with a lower morbidity [8, 21]. However, some surgeons feel that an anterior thoracoscopic release is not as effective as an open release. This is because they believe that a successful anterior spinal release requires a rib-head resection and a radical discectomy, which cannot be easily performed through VATS [5, 23]. Although studies using animals and cadavers have demonstrated that a thoracoscopic release can improve spinal flexibility [6, 20], it was not performed on actual patients with scoliosis. Thus, there is no definitive proof

in human patients with scoliosis that the thoracoscopic spinal release is effective. Although some clinical studies have demonstrated that combined VATS and posterior spine fusion resulted in good scoliosis correction [2, 21, 22], they did not assess the actual flexibility of the scoliosis and therefore were not able to directly demonstrate that the thoracoscopic release added to the spinal flexibility.

The use of the fulcrum-bending radiograph, which reflects the spinal flexibility and accurately predicts the post-operative coronal deformity correction, provides an opportunity to assess the effectiveness of thoracoscopic release in vivo [24, 27, 28]. The five cases included in this study had stiff curves, with a pre-operative fulcrum-bending angle of more than 40°, a mean pre-operative fulcrum flexibility of only 39%, and a mean Cobb angle of 71°. As these cases had staged surgery, we were able to obtain a post-release fulcrum-bending radiograph for comparison with the pre-release and post-operative Cobb angles. After anterior thoracoscopic release, flexibility was increased from 39 to 54%, thus representing a direct proof that the procedure can improve the spinal flexibility, in our cases by an average of 15%.

One patient (Case 5) was unable to lie on the fulcrum to perform a post-release fulcrum-bending radiograph due to wound pain. Nevertheless, case 5 has been included in the analysis, as a comparison of the pre-release fulcrum-bending radiograph with the post-operative radiograph will still provide an indirect evidence on the success of a thoracoscopic release (Table 2). For those who were able to lie on the fulcrum, we found the technique reliable. In this limited series of four cases, the post-release fulcrum-bending radiograph correlated well with the post-operative result.

It should be noted that the previous work on the fulcrum-bending radiograph are based on the use of

Table 2 Measured Cobb angles for each case (For case 5, it was not possible to perform a post-release fulcrum-bending XR because of wound pain)

	Case 1	Case 2	Case 3	Case 4	Case 5	Mean
Pre-operative AP standing	65	76	75	78	61	71
Pre-release fulcrum bending	43	41	45	45	40	43
Post-release fulcrum bending	35	28	40	30	N/A	33
AP standing latest follow-up	32	28	30	28	26	29

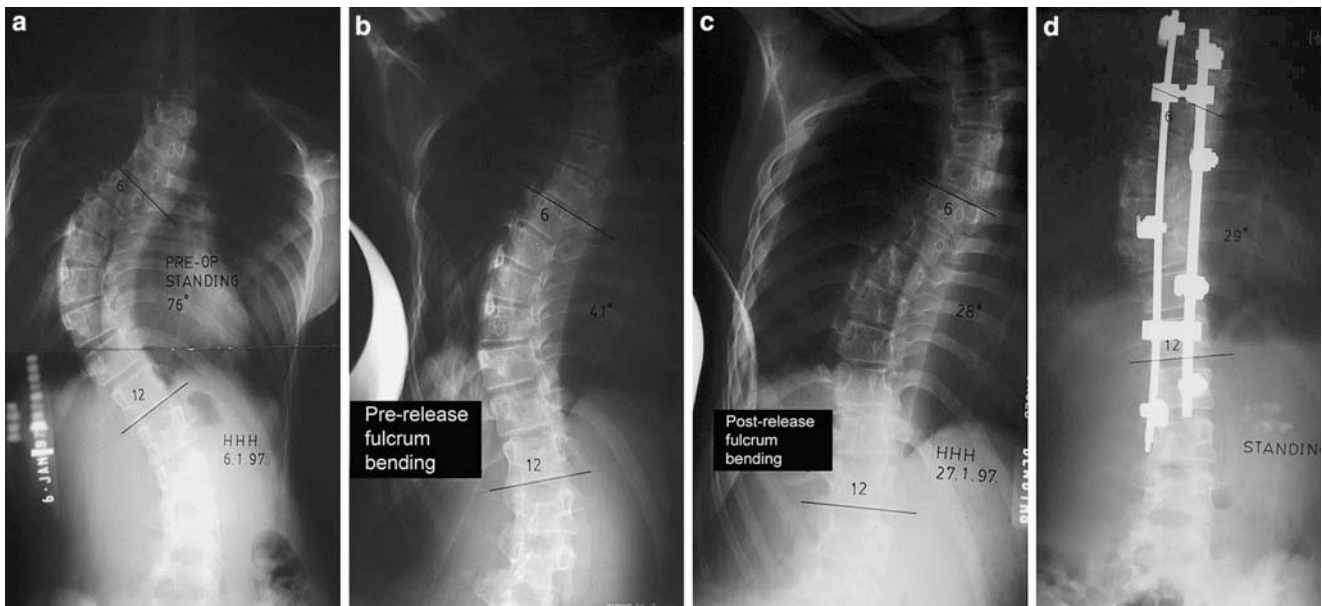


Fig. 1 **a** Pre-operative anteroposterior standing radiograph of case 2, showing a 76°-curve from T6 to T12. **b** Pre-release fulcrum-bending radiograph showing a correction to only 41°. **c** Fulcrum-bending radiograph taken 1 week after an anterior

thoracoscopic release of four levels, showing an improvement in the flexibility to 28°. **d** Post-operative standing radiograph taken 1 week after the posterior correction, showing the curve correction to 29°

hooks and hybrid systems only [4, 15]. The predictability of this method with reference to the use of pedicle-screw fixation is not known. It is widely believed that pedicle-screw systems give a superior degree of correction when compared to hook systems, and may obviate the need to perform anterior releases. However, there is no published data, which directly compares the two systems, taking into account the spinal flexibility.

The authors are aware of two different ways to measure Cobb angles before and after surgery. One method is to determine the Cobb angles in the pre-operative standing radiograph, and then to use the same levels throughout, although in the post-operative radiograph, the same measured levels may no longer be the most “tilted” vertebra. The alternative method is always a measure from the most “tilted” levels even though the levels may change between pre- and post-operative radiographs. While the authors prefer the former method, use of the latter method would not alter the results. Using the presented case as an example (Fig. 1), the pre-operative Cobb angle from T6 to T12 was 76°, the pre-release Cobb angle from T7 to T10 was 50°, the post-release Cobb angle from T8 to T10 was 40°, and the final Cobb angle from T7 to T10 was 40°.

The technique of anterior spinal release is different amongst different surgeons, while some do only a discectomy; others routinely remove the rib-heads, and even disrupt the posterior longitudinal ligament. The use of VATS limits the number of structures that can be easily

released due to limitations in visualization and access to all disc levels. This study is not comparing the open thoracotomy and release with the thoracoscopic anterior release; this is because no data is available for the former. Moreover, an evaluation of open release versus thoracoscopic release using the present method is not possible, as patients undergoing the open release would still have a painful wound, which would prevent them from lying sideways over a fulcrum.

One potential pitfall of this study is that three different types of implants were used, while the original study on the fulcrum-bending radiograph was based on TSRH [4]. It may be possible that different implants vary in their ability to correct scoliosis and therefore invalidate the indirect assessment. However, the authors feel that this is unlikely because it has been demonstrated by the same group that there was no significant difference in the ability of different instrumentation systems to correct thoracic scoliosis [18]. Moreover, the direct comparison of fulcrum flexibility before and after an anterior release would still stand.

This study was performed in the early part of our experience with thoracoscopic anterior release, hence relatively few discs were released and the surgeries were staged. However, it did serve the purpose of demonstrating that thoracoscopic anterior release does result in an improvement in spinal flexibility. With increasing experience, the authors tend to release five to six discs per patient and the posterior surgery is performed on the same day.

With the advent of new techniques and instrumentation, the indications for a thoracoscopic release may change in time. In particular, pedicle-screw systems appear to provide a better correction of large magnitude curves [9, 13, 26]. However, to date, there are no randomized studies comparing hooks versus screw systems, nor a correlation of the correction to spinal flexibility assessment, such as the fulcrum-bending correction

index [17, 18]. Additionally, the use of anterior instrumentation systems may mean that such surgeries are carried out as a single-stage anteriorly, avoiding the need for posterior surgery [3, 14].

In summary, this is the first study to provide a direct in vivo evidence demonstrating the effectiveness of thoracoscopic anterior release in improving the spinal flexibility in patients with scoliosis.

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