A Less Invasive Technique for Correction of Thoracolumbar Sagittal Deformity in Ankylosing Spondylitis

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Abstract

Background Data: Ankylosing spondylitis (AS) is a chronic inflammatory disease that can severely alter the normal spinal sagittal balance resulting in functional and social disability. Although the traditional open corrective techniques have provided a great radiographic improvement, they are associated with relatively high morbidity and mortality in an already vulnerable patient with several medical comorbidities. Therefore, a new less invasive technique has been developed in an attempt to achieve both radiographic and clinical improvement while minimizing the possible surgical risks of conventional open approaches.

Purpose: To present an innovative less invasive technique for management of thoracic and/or lumbar sagittal imbalance in AS and to evaluate the morbidity, clinical results and radiographic correction following the use of this technique.

Study design: Retrospective analysis of prospectively collected data.

Methods: Between September 2008 and September 2013, 51 patients (43 males and 8 females) with thoracic and/or lumbar sagittal imbalance due to AS were operated upon. Those patients underwent minimally invasive dorso-ventral osteotomy and reconstruction plus posterior percutaneous instrumentation in the same prone position. Sagittal vertical axis (SVA), T1 pelvic angle (TPA), angle of fusion levels (AFL) and chin-brow vertical angle (CBVA) were used to evaluate radiographic outcomes and degree of correction. Clinical outcomes were assessed by Oswestry Disability Index (ODI) and visual analogue scale (VAS).

Results: The mean age at operation was 49.02 years. The mean operative time was 419.31 min with a mean blood loss of 698.24 ml. One third of the patients underwent more than one single dorso-ventral osteotomy. All clinical and radiographic parameters (except for PI) showed a statistically significant improvement after surgery (P< 0.0001). The mean correction of AFL was 32.23±10.16° while the mean loss of correction was 2.00±2.89°. In the present study, not only the mean ODI improved significantly from 48.67±7.86 preoperatively to 19.25±10.22 at the latest follow up (P< 0.0001), but also 94% of the patients showed >30% improvement from the baseline ODI. Moreover, the changes in ODI were significantly related to...
the changes in SVA, TPA, AFL and CBVA. Dural tear and transient radiculopathy were the most common complications.

**Conclusion:** This technique has obvious advantages in reducing blood loss, optimizing correction and reconstruction, facilitating the postoperative course, and providing satisfactory clinical outcomes. We believe that this novel technique, although technically demanding, offers a safe and effective alternative for traditional open surgery in managing thoracic and/or lumbar sagittal imbalance due to AS. (2018ESJ159)

**Keywords:** ankylosing spondylitis; minimally invasive spine surgery; sagittal imbalance

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**Introduction**

Ankylosing spondylitis (AS) is a seronegative spondyloarthitis which primarily affects the axial skeleton. The incidence of AS is between 0.5 and 14 per 100,000 people per year with male to female ratio being 2:1. The exact aetiopathology of AS remains unclear. The disease affects the entheses leading to disabling ankylosis of the involved joints. HLA-B27 is positive in 90–95% of AS patients. The influence of other environmental factors in AS has been suspected. Spinal sagittal imbalance is a functionally and socially disabling condition affecting more than 30% of AS patients. Patients with such deformity find it difficult to sit, stand and/or lie down comfortably. Their forward gaze is usually impaired and their gait cycle can be severely compromised. Back Pain and fatigue may occur due to muscle exhaustion during their attempt to compensate for this deformity.

In spite of the great advances in medicine, until now there is no known effective joint replacement in the field of the spine that can restore part of the lost spinal movements. The role of surgery is firstly to restore a balanced spine by recreating an acceptable sagittal contour and secondly to eradicate sites of localized painful angular instability (Anderson’s lesions). This can substantially improve the cosmetic and functional effects of the deformity, reduce the patients’ pain, and increase their ability to stand and walk comfortably without fatigue.

Several types of osteotomies have been used over the past 70 years for correction of thoracic and/or lumbar deformity in AS including; Smith Peterson’s osteotomy (SPO), dorso-ventral osteotomy (DVO), pedicle subtraction osteotomy (PSO) and polysegmental wedge osteotomies (PWO). Currently, these osteotomies are performed through traditional open approaches. However, owing to the special nature of AS and its associated medical comorbidities, these conventional surgeries are associated with substantial surgical risks including significant blood loss, increased infection rate, significant damage to soft tissue and muscle and a high complication rate.

Recently, several minimally invasive techniques have been developed to address the high perioperative morbidity of traditional open surgery for adolescent and adult idiopathic scoliosis. Until now, no single study has reported or evaluated the use of simultaneous minimally invasive anterior and posterior approaches for the management of AS kyphotic deformity. Therefore, our study aims to evaluate the clinical results, radiographic correction and morbidity of this new minimally invasive technique.

**Materials and Methods**

Between September 2008 and September 2013, 51 AS patients with thoracic and/or lumbar sagittal imbalance were treated surgically through combined anterior and posterior minimally invasive approaches in the same sitting and in the same position i.e. prone position. The indications for surgery were inability to walk, sit, stand or lie down comfortably, impairment of the horizontal visual field, severe chronic pain non-responsive to conservative management. The patients’ clinical data, radiographs and standardized photographs were prospectively collected in our department database and retrospectively analyzed. Patients with associated cervical deformities requiring osteotomies exclusively there or additionally in the thoracic and/or in the lumbar region were excluded. The present study included forty-three males (84.31%) and eight females (15.69%) with a mean age at surgery of 49.02±8.01 years (Range, 34-
All patients were followed for a minimum of 24 months postoperatively.

**Clinical Data:**
The recorded clinical parameters included: Age at time of operation, sex, height, occiput to wall distance (OWD), operative time, blood loss, length of ICU stay and complications. The clinical outcome was assessed using VAS and ODI questionnaire completed by the patients preoperatively and at the latest follow up visit.

**Radiographic Parameters and Evaluation:**
Radiographic parameters were obtained from standing anteroposterior and lateral whole spine radiographs performed preoperatively, immediately postoperatively and at the latest follow up. The following parameters have been measured: Pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL), thoracic kyphosis (TK), sagittal vertical axis (SVA), T1 pelvic angle (TPA) and angle of fusion levels (AFL). Chin-brow to vertical angle (CBVA), defined as an angle measured between the vertical line passing through the center of the extended knee and hip joints and the line joining the patient brow and chin, was measured on the standing clinical photographs of the side-view of the patients taken preoperatively, immediately postoperatively and at the latest follow up visit. All radiographic measurements were made using Surgimap Spine, a dedicated and validated software (Nemaris, Inc., New York, NY, USA).

**Surgical Technique:**

**Anesthesia and Positioning:** Under general anesthesia using a single-lumen endotracheal tube, the patient was placed prone on special padded cylindrical cushions connected to the operating table. The proximal cushion supports sternum and the shoulders and the distal one supports the pelvis (Figure 1).

**Posterior percutaneous spinal instrumentation:**
Pedicule screws were placed percutaneously through multiple transverse skin incisions (1.5 cm) under control of two C-arm image intensifiers in two perpendicular planes (anteroposterior and lateral) (Figure 2). The cannulated polyaxial screws were inserted bilaterally from proximal to distal through the pedicles of the targeted spinal levels using the anatomical landmarks described by Wiesner et al. In order to prevent failures of fixation in the already osteopenic bone of an AS patient, the forces applied to the construct should be equally distributed over multiple anchor points. Therefore, our instrumentation included at least three levels above and three levels below the osteotomy.

**Posterior mini open microscopic assisted osteotomy:**
One or more V-shaped osteotomies were performed at the most commonly involved segments in the kyphosis. A 3 cm midline skin incision was made followed by subperiosteal dissection of spinous process and lamina of the cranial vertebra plus ossified interlaminar space to the caudal vertebra in respect to the osteotomy envisaged. This osteotomy started in the interlaminar space at the midline and proceeded laterally and cranially ending in the intervertebral foramen. It entailed resection of the ossified supraspinous and interspinous ligaments, the ligamentum flavum and part of the spinous process, and lamina as well as inferior facets of the cranial vertebra (Figure 3). The osteotomy was fashioned in away so that it could be closed safely without compressing any neural structure. In the presence of scoliosis, the osteotomy was made larger in the convex side.

**Anterior endoscopically assisted osteotomy:**
A keyhole incision (3 cm) was placed in the chest cage opposite to the level of the apex of kyphosis in the posterior axillary line. A second portal (1.5 cm) was used for insertion of the endoscope. A special set of instruments was used to retract lung and aorta and for keeping an adequate and safe access to the target (Figure 4-A, B, C, D). For osteotomies caudal to the L1/L2 former disk space, the anterior spine was similarly treated in the prone position via a retroperitoneoscopic approach.

**Correction of the deformity:** After meticulous division of all bony elements anterior to the spinal cord, the effect of gravity assisted by angulation of the operating table resulted in simultaneous closure of the posterior osteotomy and opening of the anterior osteotomy (Figure 4-E). In this way, the trunk is gradually extended and the deformity is corrected smoothly.

**Completion of the posterior Fixation:** The rods were contoured according to the desired correction. Beginning from the cranial most screw, they were...
pushed successively through the screw-extensions and temporarily fixed using the rod-pushers. Definitive correction and fixation was achieved by applying compression to the osteotomy site or sites via temporary extensions of the polyaxial screw-heads. Aided by a torque wrench, the fixation bolts in the screw heads were tightened to permanently fix the rod-screw junction.

**Reconstruction of the anterior column:** The bony gap(s) created through correction were then bridged with cages applied through the thoracoscopic anterior route. (Figure 4-F) Always the bone chips derived from the posterior osteotomy proved to be sufficient for filling the implant and residual osteotomy voids.

**Closure of the surgical wounds:** The wound of the thoracoscopic working channel is closed in layers using absorbable sutures. The wounds of the percutaneous screws are closed also in layer. Skin incisions are closed with band aids. (Figure 5)

**Postoperative management:** The patients were allowed to ambulate from the first postoperative day without the need for orthosis. The chest tube was removed depending on the amount of discharge, on average at the second postoperative day.

**Surgical Decision Making:** We classified our patients into three groups according to location of the deformity. The first group included 9 patients with isolated kyphosis or loss of lordosis of the lumbar spine. This group was managed by lumbar DVO. The second group consisted of 28 patients with significant thoracic or thoracolumbar kyphosis and fairly normal lumbar lordosis. This group underwent DVO at the lower thoracic spine, thus avoiding osteotomy at the mid thoracic spine, where limited correction due to ankylosed costovertebral joints and higher risk of neurological insult to the less mobile thoracic cord has to be expected. The third group encompassed 14 patients with generalized kyphosis of thoracic and lumbar spine. In this group, spinal alignment was achieved by a compensatory DVO in the lumbar spine. In 16 patients with severe deformity, two osteotomies was performed. A third osteotomy was indicated in 2 patients with more severe deformity to achieve the desired correction.

**Statistical Analysis:** Statistical analysis was performed using Graph Pad Prism for windows version 5.04. The patients’ clinical and radiographic data were described as the mean ± standard deviation. A paired sample t test was performed to determine the differences between preoperative and postoperative VAS and ODI. A repeated measure analysis of variance (ANOVA) was used to compare clinical and radiographic parameters at three different time-points. (Preoperative, postoperative and latest follow up). Correlations between changes in spino-pelvic parameters and changes in ODI were calculated using Pearson Coefficient. Statistical significance was accepted when p value was less than 0.05.

**Results**

**Operative Procedure:** The mean total operative time was 419.3±100.2 minutes (163.5±52.5 minutes for the anterior procedures and 253.8±69.3 minutes for the posterior procedures). The mean blood loss was 698.2±434.1 ml. A total number of 71 posterior osteotomies were performed in 51 patients subdivided as the following: single osteotomy in 33 patients, two osteotomies in 16 patients and three osteotomies in 2 patients.

**Clinical Results:** There was a statistically significant increase of around 10 cm in the height gain of the patients: from 164.6±8.8 cm preoperatively to 175.1±8.3 cm postoperatively (P<0.0001) (Table 1). There was also a statistically significant decrease in the mean occiput to wall distance (OWD): from 28.4±7.96 cm preoperatively to 11.5±4.02 cm postoperatively (P<0.0001) (Table 2). The mean ODI improved from 48.67±7.86 to 19.25±10.22 at the latest follow up and the mean VAS also decreased from 4.73±2.38 preoperatively to 1.80±1.56 at the latest follow up. Comparing preoperative and latest follow up values for ODI and VAS using paired t-test confirmed that a statistically significant decrease in disability and pain was achieved (P<0.0001 for both ODI and VAS).
**Radiographic Results:**

All radiographic parameters (except for PI) showed a statistically significant difference between preoperative and postoperative measurements and also between preoperative and latest follow up measurements with little difference between postoperative and latest follow up measurements (Table 2). There were no significant correlations between changes in ODI and changes in PT, SS, LL, and TK. On the contrary, changes in ODI were significantly related to changes in TPA, SVA, AFL, height, CBVA and OWD (Table 2).

**Complications:**

Complications were divided into three categories: intraoperative, early postoperative and late postoperative (Table 3).

### Table 1. Changes in Radiographic and Clinical Parameters

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>PT°</td>
<td>32.52±10.83</td>
<td>23.46±8.58</td>
<td>24.17±8.55</td>
<td>9.05±7.00</td>
<td>0.71±3.89</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.5986</td>
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<tr>
<td>PI°</td>
<td>53.92±10.84</td>
<td>54.03±10.79</td>
<td>54.19±10.77</td>
<td>-0.11±1.40</td>
<td>0.16±0.85</td>
<td>&lt;0.0001</td>
<td>0.7018</td>
<td>0.5439</td>
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<tr>
<td>SS°</td>
<td>21.61±8.40</td>
<td>30.77±6.98</td>
<td>30.23±7.13</td>
<td>9.16±7.00</td>
<td>0.54±3.44</td>
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<td>&lt;0.0001</td>
<td>0.7961</td>
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<tr>
<td>LL°</td>
<td>-31.51±20.18</td>
<td>-50.24±8.78</td>
<td>-49.54±8.90</td>
<td>18.7±18.33</td>
<td>0.70±2.53</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.1625</td>
</tr>
<tr>
<td>TK°</td>
<td>65.37±14.21</td>
<td>53.94±11.45</td>
<td>54.65±10.12</td>
<td>11.42±9.77</td>
<td>0.70±3.00</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.2983</td>
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<tr>
<td>TPA°</td>
<td>36.77±13.63</td>
<td>21.85±9.54</td>
<td>23.16±9.95</td>
<td>14.92±8.54</td>
<td>1.32±2.43</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.0010</td>
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<tr>
<td>SVA (mm)</td>
<td>129.46±68.88</td>
<td>56.91±43.72</td>
<td>63.54±48.87</td>
<td>72.55±49.52</td>
<td>6.62±20.10</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.0678</td>
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<tr>
<td>AFL°</td>
<td>11.77±27.11</td>
<td>-20.46±27.29</td>
<td>-18.45±27.35</td>
<td>32.23±10.16</td>
<td>2.00±2.89</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.59±8.79</td>
<td>175.09±8.30</td>
<td>174.50±8.31</td>
<td>10.50±5.17</td>
<td>0.59±0.88</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>CBVA°</td>
<td>39.40±8.82</td>
<td>7.28±7.15</td>
<td>8.57±7.95</td>
<td>32.12±8.21</td>
<td>1.29±2.45</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.0013</td>
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<tr>
<td>OWD (cm)</td>
<td>28.41±7.96</td>
<td>11.49±4.02</td>
<td>12.42±4.61</td>
<td>16.92±6.30</td>
<td>0.93±1.66</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.0006</td>
</tr>
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</table>

A repeated measure analysis of variance (ANOVA) with a Greenhouse-Geisser correction was used to compare clinical and radiographic parameters at three different time-points. (Preoperative, postoperative and latest follow up). Preop, preoperative; Postop, Postoperative; C, Correction; CL, Correction loss; PT, Pelvic tilt; PI, Pelvic incidence; SS, sacral slope; LL, Lumbar lordosis; TK, Thoracic kyphosis; TPA, T1 pelvic angle; SVA, Sagittal vertical axis; AFL, Angle of fusion levels; CBVA Chin-brow vertical angle; OWD, Occiput wall distance.

### Table 2. Correlation between Changes in ODI (Δ ODI) and Changes (Δ) in Radiographic and Clinical Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Δ ODI</th>
<th>R</th>
<th>P value</th>
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<tbody>
<tr>
<td>Δ PT</td>
<td>0.09209</td>
<td>0.260</td>
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<tr>
<td>Δ SS</td>
<td>0.1291</td>
<td>0.183</td>
<td></td>
</tr>
<tr>
<td>Δ LL</td>
<td>0.01134</td>
<td>0.469</td>
<td></td>
</tr>
<tr>
<td>Δ TK</td>
<td>0.1538</td>
<td>0.141</td>
<td></td>
</tr>
<tr>
<td>Δ TPA</td>
<td>0.2592</td>
<td>0.033</td>
<td></td>
</tr>
<tr>
<td>Δ SVA</td>
<td>0.3090</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>Δ AFL</td>
<td>0.3401</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td>Δ Height</td>
<td>0.2331</td>
<td>0.0498</td>
<td></td>
</tr>
<tr>
<td>Δ CBVA</td>
<td>0.3681</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Δ OWD</td>
<td>0.3411</td>
<td>0.007</td>
<td></td>
</tr>
</tbody>
</table>

ODI, Oswestry Disability Index; PT, Pelvic tilt; PI, Pelvic incidence; SS, sacral slope; LL, Lumbar lordosis; TK, Thoracic kyphosis; TPA, T1 pelvic angle; SVA, Sagittal vertical axis; AFL, Angle of fusion levels; CBVA Chin-brow vertical angle; OWD, Occiput wall distance.

### Table 3. Summary of Complications

<table>
<thead>
<tr>
<th>Complication</th>
<th>No.</th>
<th>%</th>
</tr>
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<tbody>
<tr>
<td>Intraoperative</td>
<td></td>
<td></td>
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<tr>
<td>Dural openings</td>
<td>5</td>
<td>9.8</td>
</tr>
<tr>
<td>Translation at the osteotomy site</td>
<td>3</td>
<td>5.9</td>
</tr>
<tr>
<td>Early postoperative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transient radiculopathy</td>
<td>5</td>
<td>9.8</td>
</tr>
<tr>
<td>Paralytic ileus</td>
<td>2</td>
<td>3.92</td>
</tr>
<tr>
<td>Wound infection</td>
<td>2</td>
<td>3.92</td>
</tr>
<tr>
<td>Cage mal-position</td>
<td>2</td>
<td>3.92</td>
</tr>
<tr>
<td>Failure of fixation with rod dislocation</td>
<td>1</td>
<td>1.96</td>
</tr>
<tr>
<td>Ventilatory support &gt; 72 hours</td>
<td>1</td>
<td>1.96</td>
</tr>
<tr>
<td>DVT and pulmonary embolism</td>
<td>1</td>
<td>1.96</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>1</td>
<td>1.96</td>
</tr>
<tr>
<td>Retrograde ejaculation</td>
<td>1</td>
<td>1.96</td>
</tr>
<tr>
<td>Late postoperative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudoarthrosis</td>
<td>2</td>
<td>3.92</td>
</tr>
<tr>
<td>Retrograde ejaculation</td>
<td>1</td>
<td>1.96</td>
</tr>
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</table>
Figure 1. Patient position on the operating table

Figure 2. Percutaneous instrumentation technique

Figure 3. Posterior mini open microscopic assisted osteotomy

Figure 4. (A) The two-portal thoracoscopic approach. (B) Pleural opening and spine exposure. (C, D) Thoracoscopic anterior osteotomy. (E) Correction of the deformity. (F) Reconstruction of the anterior column.
**Figure 5.** A) Closure of the surgical wounds. (B) Patient before and (C) after surgery.

**Figure 6.** (Case 1): A 54–year-old man with isolated thoracic hyperkyphosis and normal lumbar lordosis. (A) Preoperative lateral radiograph. (B) Immediate postoperative lateral radiograph after thoracoscopic DVO T12-L1 and reconstruction with cage. (C) Lateral radiograph at the latest follow up showing maintained correction. (D,E,F) Preoperative, postoperative and last follow up clinical photos showing improved horizontal visual field.

**Figure 7.** A 49–year-old man with loss of the normal lumbar lordosis. (A) Preoperative lateral radiograph. (B) Immediate postoperative lateral radiograph after retroperitoneoscopic DVO L3-4 and reconstruction with cage. (C) Lateral radiograph at the latest follow up showing solid fusion with maintained correction. (D,E,F) Preoperative, postoperative and last follow up clinical photos showing marked improvement in the horizontal visual field.
Discussion

Surgical Planning:
Classifications and management plans have been developed to address the spinal deformity in AS.\textsuperscript{16,31} We believe that every patient should have its own custom made treatment plan taking in consideration several factors including: type and severity of deformity, site of maximum deformity, bone quality, amount of correction needed, general medical condition of the patient, hip condition and occupation of the patient.

Variable methods have been described to estimate the correction required. However, the surgical results not always match the expected outcomes of the preoperative planning.\textsuperscript{28} During our preoperative planning, CBVA varied from 31° to 75° with a mean of 39.40°. We used this angle as a rough estimation for the amount of correction needed. During surgery, the amount of correction was first estimated after the opening of the primary osteotomy with an intraoperative lateral radiograph. Residual amount of correction was accomplished by either increasing the opening of the primary osteotomy with an intraoperative lateral radiograph. Residual amount of correction was accomplished by either increasing the opening of the primary osteotomy (titrated procedure) or adding a second osteotomy. Both options can be utilized easily at the anterior and the posterior side without the need for changing the patient’s position.

Surgical Technique:
Although the correction can be done entirely through a posterior approach by PSO, risks of neurological deficits, increased blood loss, and residual instability resulting in translation and alteration in the spine geometry make combined posterior and anterior approaches a good alternative. Adding the anterior approach has also several advantages\textsuperscript{6} including: (1) It ensures that the axis of correction remains at the level of the spinal canal minimizing any geometrical changes in length of the dura and cord as well as the height of the intervertebral foramen. It also facilitates complete closure of posterior osteotomy, allowing a higher angle of correction in relation to stretching or compressing the spinal canal. (2) It enables meticulous division of all bony elements anterior to the cord to ensure that the osteotomy runs through the disc and subsequently avoiding translation of the vertebral column, this being particularly important in bamboo spine. (3) It allows guided titrated gradual opening of the anterior osteotomy, reducing the risk of the aortic rupture due sudden stretch or avulsed bony spike. (4) It allows also decortication of the end plates and reconstruction of the anterior column for rapid bony consolidation thus decreasing the risk for loss of correction, implant failure and pseudoarthrosis. (5) It makes direct anterior decompression of the cord possible, this particularly important in longstanding Andersson’s lesions.

La Chapelle,\textsuperscript{19} in 1946 and later Bradford et al,\textsuperscript{8} in 1987 introduced the concept of combined anterior and posterior approaches for management of lumbar and thoracic kyphotic deformity in AS. Bridwell et al,\textsuperscript{10} reported that anterior grafting and reconstruction may be necessary after achieving substantial correction with SPO. However, the necessity for changing the patient’s position twice in addition to the high morbidity associated with
conventional anterior approaches, made surgeons prefer the posterior only approach.

Boehm simplified the complexity of combined anterior and posterior correction in AS. The possibility to perform anterior and posterior procedures safely in the same prone position along with reducing trauma of the anterior approach due to the use of thoracoscopy has obvious advantages in reducing blood loss, optimizing correction and reconstruction, facilitating postoperative course, and reducing overall costs of treatment. The mean total operative time in the present study was 419.31 min compared to 186 min for SPO and 240 min for PSO in Liu et al, meta-analysis. Although, the prone position saved time and allowed us to perform both anterior and posterior procedures in a relatively good total operative time, however this issue is still the major drawback of this technique.

One of the most important advantages of this minimally invasive technique is the decreased blood loss. In the current study, the mean intraoperative blood loss was 698.24 ml compared to 1307 ml for SPO and 2012 ml for PSO as reported in Liu et al, meta-analysis. The mean ICU stay was 2 days compared to 3 days in a study by Arun et al.

**Radiographic Outcome:**

By performing the osteotomy at or near the apex of the deformity, we were able to provide harmonic correction of thoracic hyperkyphosis (from 65.37±14.21° preoperatively to 53.94±11.45° postoperatively), normalization of the thoracolumbar junction (from 25.92±11.84° preoperatively to 4.563±12.88° postoperatively) and restoration of the normal lumbar lordosis (from -31.51±20.18° preoperatively to -49.26±11.41° postoperatively).

In the same time, we achieved a biomechanically sound improvement in sagittal balance. Therefore, the proximal junctional kyphosis and hence, the loss of correction of sagittal balance has not been a problem in our patients. The preoperative SVA has improved from 129.5±68.88 mm preoperatively to 56.91±43.72 mm postoperatively which was non-significantly different from that recorded the end of follow up 65.47±49.89 mm. TPA showed also significant improvement from 36.77±13.63° preoperatively to 21.84±9.537° postoperatively.

A recent meta-analysis of published studies concentrating on treating thoracolumbar kyphotic deformity due to AS with SPO and/or PSO, reported that mean lumbar correction was 32.44° for SPO and 35.33° for PSO. In an earlier structured review performed by Van Royen et al, loss of correction was 6° in SPO and 2.7° in PSO. In our study, the mean correction of AFL was 32.23±10.16° while the mean loss of correction was 2.00±2.89°. Comparing our results with those from previous studies, we had somewhat less correction but in the same time this correction was maintained without great loss. This might be related to reconstruction of the anterior column which maintained the correction. Even when fusion was delayed we did not experience a dramatic loss of correction.

**Clinical Outcome:**

Halm et al, used a questionnaire-based instrument for the first time to measure the clinical outcome in AS patient who underwent corrective surgery. This retrospective study showed a significant improvement in the clinical outcome. Kim et al, reported improvement in the modified arthritis impact measurement scale (AIMS) used for assessment of the clinical outcome. Recently, several studies have emphasized the correlation between sagittal spinopelvic parameter and clinical outcome measured by health-related quality of life (HRQOL) scores in the setting of adult spinal deformity. However fewer studies have investigated this correlation in AS patients and their results are contradicting. In a prospective cohort, Shin et al, found that spinopelvic parameters (PT, SS, LL, TK and SVA) significantly correlate with ODI. This was also observed in the retrospective study conducted by Lin et al, to analyze the correlations of spinopelvic parameters with the clinical outcomes of AS patients after corrective surgery. On the contrary, Kim et al, confirmed the relationship between SVA and postoperative ODI, however they denied any significant correlation between other spinopelvic parameters (PI, PT, LL and TK) and ODI.

In the present study, not only the mean ODI significantly improved from 48.67±7.86 preoperatively to 19.25±10.22 at the latest follow up (P<0.0001) but also 94% of the patients showed >30% improvement from the baseline ODI.
Moreover, changes in ODI were significantly related to changes in global sagittal parameters (TPA, SVA and CBVA), changes in AFL (degree of correction) and changes in clinical parameters (height and OWD). On the other hand, there were no significant correlations between changes in ODI and changes in pelvic parameters (PT and SS) or changes in local sagittal parameters (LL and TK), which is consistent with Kim et al. results. This might be due to the rigidly fused spine in AS, where correction performed in the relevant segments does not accompany with compensatory changes in other spinal or pelvic levels.

**Complications:**

Dural tears are common complications in corrective osteotomy for AS deformity. The dura is often extremely thin and sometimes ossified together with the ligamentum flavum. We had five dural openings. All of them were minimal and sealed with fibrin glue and TachoSil (Takeda Pharma AG, Freienbach, Switzerland). Complete closure of the posterior osteotomy prevented any postoperative CSF leakage.

Sagittal translation at the osteotomy site is more likely to occur when the osteotomy is performed at the apex of severe lumbar deformity. It has been reported in SPO with an incidence of (27%) and it is associated with increased risk of neurological insult. We had three patients of sagittal translation; two were detected intraoperatively and reduced immediately without any neurological sequel. In the third patient, the translation was minimal with free intervertebral foramens as seen in the intraoperative x-ray. However, the patient developed bilateral quadriceps weakness postoperatively and CT showed increased translation with collapsed intervertebral foramens. Therefore, an anatomical reduction of the translation to restore the height of the intervertebral foramens plus additional decompression was done in the same day. The patient recovered completely within 3 months. The three patients had a severe lumbar deformity which required two osteotomies and translation occurred in the lower one. The use of temporary fixation rods helps to avoid sudden translation.

Five patients had transient radiculopathy postoperatively; one was due to sagittal translation and required immediate revision surgery. Another patient had quadriceps and iliopsoas weakness due femoral nerve palsy by an inguinal hematoma, which was managed conservatively. We believe that inadequate padding during this prolonged procedure was the cause of hematoma. All five patients showed complete neurological recovery at the end of follow up.

Early postoperative failure of fixation occurred in one patient which necessitated a percutaneous revision surgery with extension of the posterior fixation. One patient showed signs of hemodynamic instability with tender abdomen two hours post-surgery. Abdominal CT revealed ruptured spleen with intra-abdominal collection for which urgent splenectomy was done. Trans-diaphragmatic injury to the spleen by the chest tube is thought to be the cause of this complication.

During the late postoperative stage, two patients showed pseudoarthrosis at the osteotomy site. Posterior re-instrumentation and anterior decortication of the osteotomy site with cage, graft and bone morphogenetic protein (BMP) was the strategy for treatment in these two patients. One patient reported to have a retrograde ejaculation which showed partial improvement.

**Conclusion**

The described technique has obvious advantages in reducing blood loss, optimizing correction and reconstruction, facilitating postoperative course and providing satisfactory clinical outcomes. The rapid bony consolidation of the anterior column reduces the risk of correction loss or even revision surgery. Advances in the learning curve and adapted implantation technique promise to significantly reduce the very long operative time of this series. We believe that this novel technique, although technically demanding, presents a good alternative for traditional open surgery in managing thoracic and/or lumbar sagittal imbalance due to AS. The retrospective nature of our study plus the short term follow up represent its main limitations, therefore prospective and long-term studies are needed to validate these results.
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الملخص العربي

استخدام التدخل الجراحي المحدود لإصلاح تحدب الفقرات الصدري القطني لدى مرضى تيبس الفقرات

البيانات الخلفية: يعتبر مرض تيبس الفقرات من الأمراض النادرة التي تصيب العمود الفقري ولكن بالرغم من ندرته فإنه يؤدي في مرحلة المتقدمه إلى تجد الحد مع فقدان الذانان السهلي للعمود الفقري في 30% من المرضى، و ينتج عن هذا التحدب تقليص في مستوى الرؤية الأفقية لدى المرضى مع صعوبة في الجلوس، الوقوف، النوم في وضع أفقي. في هذه المرحلة من المرض ليس هناك جديوى من العلاج التحفظي ويتطلب التدخل الجراحي لتصليح هذا التشو من العمود الفقري.

الفقرة: هو دراسة ميدى فعالية استخدام التدخل الجراحي المحدود من الأمام والخلف في علاج فقدان الذانان السهمي لل الفقرات الصدري القطني لدى مرضى تيبس الفقرات.

تصميم الدراسة: دراسة لحالات إكلينيكية بتأرجج

المرضي والطرق: تكونت مادة البحث من 51 مريضا في الفترة ما بين سبتمبر 2008 وستمبر 2013 كما تراوحت أعمار المرضى بين 34 و 67 سنة انقسموا الى 43 من الذكور و 8 من النانث.

تمت دراسة المرضى قبل وبعد إجراء العمليات الجراحية إكلينيكيا وباستخدام اشعة اكس، الأشعه المقطوعية، المغناطيسية. كما تم فحص رؤى التحدب والاستجابة الجانبيه والإمامية للعمود الفقري قبل وبعد الجراحة ووضع خطة العلاج اللازمة لتصليح التحدب واستعادة الذانان السهلي للعمود الفقري. كما تم علقي جميع المرضى بواسطة الجراحة المكونة من مرحلتين (الأمام والخلف) في جلسه واحدة وفي وضع وضعت استخدام التدخل الجراحي المحدود. كما تم إجراء شفوط عمودية من الخلف والعمود لتصليح التجد مع تثبيت العمود الفقري بواسطة سامير عنق فقره وفصبان من خلال فتحات صغيرة في الجلد.

النتائج: كان متوسط الوقت الذي تستغرقه العملية 31 دقيقة وكان متوسط فقدان الدم أثناء العملية 31.398.24 مل. كما احتج ثلاث المرضى لأكثر من شق عظمي واحد إلى الوصول إلى درجة التصليح المطلوبة حيث كان متوسط درجة التصليح 32.23 درجه كما كان متوسط فقد في درجة التصليح ديرجان، وأسفرت الدراسة عن تحسن إكلينيكي في 94% من الحالات وهذا التحسن كان مصاحباً لتحسين الذانان السهمي للعمود الفقري، وكان القطع في الدم الجافي و ضع الاصاب.

المؤقت هما أكثر المضاعفات حدوثاً في هذه الدراسة.

الاستنتاج: نستنتج من هذه الدراسة ان استخدام التدخل الجراحي المحدود من الأمام والخلف في علاج فقدان الذانان السهمي لل الفقرات الصدري القطني لدى مرضى تيبس الفقرات يمكن الاعتماد عليه كبديل امن وفعال للجراحة التقليدية وما يصاحبه من مضاعفات.