



## Review Article

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# Minimally Invasive Spinal Surgery for Adult Spinal Deformity

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The purpose of this review is to present the current techniques and outcomes of adult spine deformity (ASD) surgery using the minimally invasive spine surgery (MISS) approach. We performed a systemic search of PubMed for literature published through January 2018 with the following terms: “minimally invasive spine surgery,” “adult spinal deformity,” and “degenerative scoliosis.” Of the 138 items that were found through this search, 57 English-language articles were selected for full-text review. According to the severity of the deformity and the symptoms, various types of MISS have been utilized, such as MISS decompression, circumferential MISS, and hybrid surgery. With proper indications, the MISS approach achieved satisfactory clinical and radiological outcomes for ASD, with reduced complication rates. Future studies should aim to define clear indications for the application of various surgical options.

**Keywords:** Minimally invasive spine surgery, Adult spinal deformity, Degenerative scoliosis

## INTRODUCTION

Adult spinal deformity (ASD) requires various surgical endeavor to achieve neural decompression and correction of segmental and global balance. However, ASD often related to high risk of perioperative morbidity due to its extensive surgical field. Minimally invasive spinal surgery (MISS) has been widely adopted for degenerative spine surgery because of little muscle trauma and reduced blood loss. In this respect, MISS has been attempted to adopt for the correction of ASD. The purpose of this study is to provide a comprehensive review of current literature about MISS for ASD.

## MATERIALS AND METHODS

We performed a systemic search of PubMed for literature published up to January 2018 with the following terms: “minimally invasive spine surgery” and “adult spinal deformity” and “degenerative scoliosis.” Of the 138 searched, case reports and

articles that did not focus on ASD were excluded. After extraction, 57 English articles were selected for full-text review.

## INDICATIONS

Although MISS techniques have recently gained in popularity to decrease surgical morbidity after open surgery, there are definitely limitations especially restoring severe sagittal malalignment patients. Selecting proper patients is a key to get a successful outcome. The main goals for the treatment of ASD are adequate neural decompression, restoring or maintaining sagittal and coronal balance and achieving bone union. Mummaneni et al.<sup>1</sup> suggested an algorithm for minimally invasive spinal deformity surgery. Based on preoperative radiological parameters, patients were stratified into different surgical strategies, ranging from MISS decompression only or selective fusion to open surgery with osteotomies. MISS technique is frequently utilized for patients with smaller coronal deformities, a sagittal vertical axis under 6 cm, a baseline pelvic incidence – lumbar lordosis mis-

match under  $30^\circ$ , and a pelvic tilt of under  $25^\circ$ .<sup>2</sup>

## SURGICAL TECHNIQUE

For patients with symptoms of central and lateral recess stenosis or foraminal stenosis accompanying mild spinal deformity, neural decompression is a treatment goal. MISS decompression technique can be utilized for these patients. Decompression using tubular retraction system or 1-level MISS fusion may be a treatment option.<sup>1</sup> Circumferential MISS (cMISS) technique is composed of  $360^\circ$  deformity correction with anterior interbody support and posterior instrumentation through MISS approach (Fig. 1).<sup>3-7</sup> Lateral lumbar interbody fusion (LLIF) followed by percutaneous pedicle screw fixation with additional lumbosacral interbody fusion by transforaminal lumbar interbody fusion (TLIF) gets most popularity in cMISS. The hybrid approach includes multilevel LLIF and posterior open instrumentation with or without osteotomies (Fig. 2).<sup>6,8-13</sup> It is different from cMISS in terms of paraspinal muscle dissection. In ASD with moderate sagittal deformity, a hybrid surgical approach involving a combination of MISS interbody fusion and open posterior approach has been used in the alternation of

traditional open posterior-only approach.<sup>9,10</sup>

Wang et al.<sup>14</sup> reported tissue-sparing mini-open pedicle subtraction osteotomy for severe ASD, which is technically feasible but has not got a popularity.

## LATERAL LUMBAR INTERBODY FUSION

For ASD, LLIF is powerful correction method in both coronal and sagittal plane deformity. The lateral transpsoas approach is direct lateral approach via splitting psoas muscle, whereas the oblique anterior-psoas approach is oblique lateral approach anterior to the psoas muscle. Both approaches is a retroperitoneal approach to the disc space via lateral annulus allowing for discectomy, distraction, and interbody fusion.<sup>15</sup> LLIF can restore intervertebral disc height resulting in indirect decompression of neural foramina without jeopardizing segmental stability because it retains the anterior longitudinal ligament (ALL) and posterior longitudinal ligament.<sup>11,16-19</sup> Furthermore, wide interbody cages that support the lateral rims of the endplate can be placed via the lateral approach, which may translate into prevention of subsidence and subsequent loss of deformity correction. In this respect, degenerative scoliosis is a main indication



**Fig. 1.** Case presentation of circumferential minimally invasive surgery for degenerative scoliosis. Preoperative anterior-posterior (A) and lateral (B) radiographs shows coronal plane deformity on lumbar spine. Lateral lumbar interbody fusion at the L1–2, L2–3, L3–4, and L4–5 followed by percutaneous pedicle screw instrumentation successfully restored coronal balance as well as the lordotic curvature of the lumbar spine (C, D).



**Fig. 2.** Case presentation of hybrid surgery for degenerative kyphoscoliosis. Preoperative anteriorposterior (A) and lateral (B) radiographs shows rigid deformity on both coronal and sagittal plane. Lateral lumbar interbody fusion from L1 to L4 and anterior lumbar interbody fusion from L4 to S1 was performed to restore anterior disc height. Additionally, open posterior segmental instrumentation from T10 to iliac fixation with multilevel grade 2 osteotomies was done to release posterior column mobility and further correction. Postoperative anteriorposterior (C) and lateral (D) radiographs shows well balanced coronal and sagittal curvature.

of LLIF. Many authors reported successful radiological and clinical outcome following LLIF and posterior instrumentation for indirect decompression and realignment of coronal balance.<sup>16,17,20-23</sup> However, the effects on sagittal balance and spinopelvic parameters are often reported to be limited. Anand et al.<sup>24</sup> presented long-term follow-up results of MISS technique for adult scoliosis. They did LLIF followed by the posterior instrumentation and fusion with axial lumbar interbody fusion for coronal deformity without sagittal malalignment. The mean preoperative Cobb angle was 24°, which corrected to 9.5°. The mean preoperative Coronal balance was 25.5 mm, which corrected to 11 mm. The mean preoperative sagittal balance was 31.7 mm and corrected to 10.7 mm. At 2- to 5-year follow-up, they reported comparable correction of ASD significantly improved functional outcomes, and excellent clinical and radiological improvement, but considerably lowers morbidity and complication rates. Although some authors reported improvement of sagittal spinopelvic parameters, most of the patients exhibited main coronal plane deformity without sagittal imbalance or with mild sagittal imbalance due to severe sagittal imbalance is not adequately treated with MISS approach.<sup>25,26</sup> Anterior column realignment (ACR) is a technique for correction of sagittal plane

deformity, which is performed via lateral transpsoas approach with ALL release and hyperlordotic cage placement.<sup>27</sup> Recent reports of minimally invasive ACR technique showed successful correction of both regional and global sagittal parameters.<sup>27-32</sup> A single level ACR restored around 30° of lordosis which is comparable with a pedicle subtraction osteotomy and 10° of reduction in the pelvic tilt.<sup>28,29</sup>

## LUMBOSACRAL INTERBODY FUSION OPTION

MISS TLIF is often used as an adjunct to multilevel LLIF or MISS posterior approaches for ASD. Wang<sup>33</sup> reported significant improvement of sagittal balance with multilevel facet osteotomies and MISS TLIF in addition to percutaneous screw fixation for ASD. Anterior lumbar interbody fusion (ALIF) offers several advantages over LLIF, including direct decompression of neural foramina, accessibility to L5–S1, less mobilization of the psoas muscle, resection of the ALL, wide discectomies, and insertion of wedge-shaped lordotic grafts that result in greater segmental lordosis restoration in the lower lumbar spine compared with TLIF.<sup>10,34</sup> However, it does carry the risks related to

mobilization of the abdominal viscera and large vessels. Anand and Baron<sup>35</sup> reported a presacral approach for discectomy and interbody fusion with low risk of surgical morbidity. However, supporting literature for this technique for ASD is not sufficient.

## PERCUTANEOUS PEDICLE SCREW AND ROD PLACEMENT

Although some selected patients are benefitable for stand-alone LLIF without posterior instrumentation,<sup>36</sup> most of ASD patients need to be stabilized and further corrected by posteriorly with pedicle screw instrumentations. Percutaneous pedicle screw instrumentation is important for the cMISS deformity surgery. Various correction maneuvers including vertical translation of apex, rebalancing of both coronal and sagittal plane with compression, distraction, and direct derotation are applicable following LLIF.<sup>35,37,38</sup> For rigid lumbosacral fixation in cMISS, Wang et al.<sup>39</sup> reported feasibility and safety of percutaneous iliac screws placement without extensive muscle exposure. Fluoroscopic guidance is essential and recent advances for image-guided surgery with navigation or robotic guidance enhance safety and accuracy of the surgery.<sup>40,41</sup>

## OUTCOMES AND COMPLICATIONS

Ever since Dakwar et al.<sup>42</sup> reported the feasibility of LLIF for adult degenerative scoliosis, for properly indicated patients, MISS approach achieved good clinical and radiological outcomes. Anand et al.<sup>4</sup> reported mean 48-month follow-up results after cMISS for moderate (Cobb angle between 30° and 75°) adult scoliosis. Mean Cobb angle and sagittal vertical axis was decreased from 42° and 51 mm preoperatively to 16° and 27 mm postoperatively. Health-related quality of life (HRQoL) scores were also improved at last follow-up with considerable lower morbidity and complication rates. However, cMISS procedure had the limitation of correction in both coronal and sagittal plane deformity.<sup>6,11,25,26,43,44</sup> Careful decision making for choosing surgical approach is mandatory in tailoring goals of deformity correction according to patients' radiological and clinical status. For similar baseline deformity, cMISS exhibits reduced construct length, reoperation rate, costs, blood loss, and hospital stays with comparable clinical radiological improvement.<sup>7,45-54</sup> Uribe et al.<sup>7</sup> reported significant decreased in mean fusion levels (4.8 for cMISS vs. 10.1 open), blood loss (488 mL cMISS vs. 1,762 mL open) and hospital stay (6.7 days cMISS vs. 9.7 days

open) in cMISS. Due to decreased surgery-related morbidity, older patients can have benefit after MISS approach for ASD in terms of HRQoL improvement.<sup>55</sup> Major complications such as massive bleeding and postsurgical infection rate is relatively less in cMISS than in open surgery. However, a complication related to surgical approach especially for LLIF should be considered. Iliopsoas weakness, temporary paresthesia, dysesthesia or numbness on thigh has been reported ranging 12.5% to 75% with LLIF.<sup>18,56</sup> Pseudarthrosis is a major issue for long-term outcome after ASD surgery. Fusion rate after cMISS surgery widely ranges from 71.4% to 100%, while overall fusion rate after ASD surgery is reported to be 93.7% (range, 59%–100%).<sup>57,58</sup> Use of bone graft substitute such as recombinant human bone morphogenetic protein-2 helps to enhance fusion rate.<sup>59</sup> Mummaneni et al.<sup>60</sup> showed the pseudarthrosis is higher in cMISS compared with hybrid group (46.6% vs. 71.6%) and overall incidence of proximal junctional kyphosis (PJK) (48.1% vs. 53.8%) and reoperation for PJK (11.1% vs. 19.2%) is similar in cMISS and hybrid group. Bae et al.<sup>10</sup> showed hybrid surgery utilizing LLIF had lower rates of PJK and mechanical failure at the upper instrumented vertebra and better HRQoL scores in comparison with open posterior surgery and hybrid surgery using ALIF, while radiological improvement was similar between 3 different surgeries for ASD with moderate sagittal imbalance. In comparison with open posterior surgery, Hybrid surgery with LLIF showed faster recovery, fewer complications and greater relief of pain and disability.<sup>9</sup>

## CONCLUSION

Satisfactory radiological and clinical outcomes can be achieved with MISS approach for ASD. Although MISS correction of deformity is not widely adoptable as open surgery, selecting a proper approach for the specific type of deformity has produced repeatable and safe results. Given currently published literature, efficacy, and limitations of MISS approach is clear. Surgeons should understand roles of various types of surgery to gain goals of deformity correction as well as reducing complications. Due to a wide range of demographic characteristics, pros and cons between different type and the combination of MISS approach are not well demonstrated. Further studies should aim to define better indications of the developing techniques.

## CONFLICT OF INTEREST

The authors have nothing to disclose.

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