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TECHNIQUES OF MINIMALLY INVASIVE SURGERY IN ADULT DEGENERATIVE SPINAL DEFORMITY : A SYSTEMATIC REVIEW

Nicholas Davis Tionata[1*], Pranajaya Dharma Kadar[2]

[1]Faculty of Medicine, University of North Sumatra, Indonesia*
[2]Departement of Orthopaedic and Traumatology, University of North Sumatra, Indonesia

Corresponding Author:
davisnicholas606@gmail.com

Abstract

Adult spinal deformities are a leading cause of pain and disability in the modern world. Advances in modern healthcare has allowed the population's life expectancy to increase substantially. Despite this, there has been a marked increase in the number of ill and disabled individuals, leading to impairment in their quality of life. In order to continue performing successfully as an adult beyond retirement age, it is imperative to avoid pain and limitations in physical activity. When an adult develops a spinal deformity, surgery can help alleviate pain and reduce disability. Adult scoliosis is defined as a spine curvature greater than 10 degrees in a patient older than 18 years; nevertheless, in more severe cases, treatment is sometimes advised. Degeneration may be accelerated by asymmetric disk/facet degeneration or osteoporotic insufficiency fractures. Recently, minimally invasive spine surgery (MIS) has been at the forefront of innovation in spine surgery. MIS spine surgery not only refers to surgery through a smaller incision, but also to a technique that strives to reduce the approach-related morbidity associated with conventional open spine surgery. According to the findings of this study, Surgeons have to be prepared to offer both open or MIS for patients. Various MIS technique and its combination including hybrid surgery are used in cases of adult spinal deformity, the appropriate technique chosen for the surgery should include factors such as the spinopelvic harmony, age and outcome prediction of each patients into consideration as each technique has its own advantages and disadvantages.

Keyword: *Degenerative Spinal Deformity; Minimally Invasive Surgical; Scoliosis; Spine Surgery*

INTRODUCTION

Deformities in the spine of adults are major cause of pain and impairment in the modern world. As the population keeps growing and life expectancy keeps going up, so does the number of people who are sick or disabled. People are not just living longer, but they are also have higher expectations of how they should be able to work and perform well thus it's important for them to stay free of pain and impairment. When an adult has a spinal abnormality, surgery can help relieve pain and improve disability.[1]

Spinal deformity is characterized as having an aberrant curvature that exceeds the accepted values of normal limits, which will be explained in subsequent sections. Scoliosis is a well-defined spinal deformity characterized by a curvature of the spine greater than 10 degrees in the coronal plane. There are several causes of scoliosis, which differ based on patient demographics. The most prevalent causes are idiopathic, neuromuscular, syndromic, congenital, and degenerative. This topic focuses mostly on adult populations affected by spinal deformity.[2]

Adult scoliosis is defined as a curvature of the spine larger than 10 degrees in a patient older than 18 years; nevertheless, therapy is often recommended for more severe instances. This sort of malformation is more commonly connected with degenerative etiologies, as the other etiologies listed are predominantly observed in pediatric populations. These degenerative alterations consist of spinal stenosis, spondylolisthesis, rotational subluxation, hyperlordosis, and stiffness. Asymmetric disk/facet degeneration or osteoporotic insufficiency fractures may accelerate degeneration.[3,4]

Minimally invasive (MIS) spine surgery has recently been at the forefront of spine surgery innovation. MIS spine surgery denotes not only surgery through a smaller incision, but also a technique that aims to reduce approach-related morbidity associated with traditional open spine surgery.[5] Traditional open surgical treatment of adult degenerative scoliosis carries perioperative risk and a lengthy recovery period. The complexity of individuals with adult degenerative scoliosis, as well as patient-specific comorbidities, adds to perioperative morbidity.[6]

In comparison to open classical surgery, MIS procedures may lower approach-related and total morbidity, making them appealing to both patients and surgeons.[7] The amount of radiographic correction and degree of clinical improvement using MIS procedures for adult spinal deformity, on the other hand, remain unknown. Furthermore, minimally invasive procedures have their own set of specific obstacles, technical constraints, and complications.[8,9]

This article review some research on minimally invasive surgical techniques in adult degenerative spinal deformity.

METHODS

For data collection, processing, and reporting, this study adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 project criteria. These issues influenced the regulations' adoption. This review of the literature examines minimally invasive surgical approaches in adult degenerative spinal deformity. Following were the inclusion criteria of the selected studies: 1) All papers had to be presented in English and had to cover minimally invasive surgical approaches for adult degenerative spinal deformities. 2) This systematic review considers articles published after 2013. 3) The study should be conducted in adult humans. Exclusion criteria, including: editorials, writings without DOI, reviews of works published before 2013, and large duplicates of journal articles will be removed from the anthology.

The search for studies to be included in the systematic review was carried out from March, 21th 2023 using the PubMed and SagePub databases by inputting the words: "minimally invasive surgical" and "degenerative spinal deformity". Where *"minimally"[All Fields] AND ("invasibility"[All Fields] OR "invasible"[All Fields] OR "invasion"[All Fields] OR "invasions"[All Fields] OR "invasive"[All Fields] OR "invasively"[All Fields] OR "invasiveness"[All Fields] OR "invasives"[All Fields] OR "invasivity"[All Fields]) AND ("surgical procedures, operative"[MeSH Terms] OR ("surgical"[All Fields] AND "procedures"[All Fields] AND "operative"[All Fields]) OR "operative surgical procedures"[All Fields] OR "surgical"[All Fields] OR "surgically"[All Fields] OR "surgicals"[All Fields]) AND ("degenerative"[All Fields] OR "degeneratively"[All Fields] OR "degeneratives"[All Fields]) AND ("spinal"[All Fields] OR "spinalization"[All Fields] OR "spinalized"[All Fields] OR "spinally"[All Fields] OR "spinals"[All Fields]) AND ("abnormalities"[MeSH Subheading] OR "abnormalities"[All Fields] OR "deformities"[All Fields] OR "congenital abnormalities"[MeSH Terms] OR ("congenital"[All Fields] AND "abnormalities"[All Fields]) OR "congenital abnormalities"[All Fields] OR "deformity"[All Fields] OR "deform"[All Fields] OR "deformabilities"[All Fields] OR "deformability"[All Fields] OR "deformable"[All Fields] OR "deformably"[All Fields] OR "deformation"[All Fields] OR "deformational"[All Fields] OR "deformations"[All Fields] OR "deformative"[All Fields] OR "deformed"[All Fields] OR "deforming"[All Fields] OR "deforms"[All Fields])* is used as search keywords.

Searches using the above keywords yielded 136 articles on PubMed, while on SagePub there were 174 articles. We then screened articles using a screening program in 2013 and above, resulting in 29 articles for PubMed and 43 for SagePub. Screening was carried out again to look for clinical trials, original article research and randomized trials and then the remaining 6 articles were produced for PubMed and 8 articles for SagePub. There are a total of 14 articles, then we remove duplicate articles, review the literature (7), no full text (2), and editorial (1). The rest of the research involved in this study were four articles.

Abstract and title of each study were utilized to assess eligibility. Therefore, historical literature is their primary information source. After examining many papers with identical results, unpublished English submissions are sought. Only studies meeting the inclusion criteria were considered for inclusion in the systematic review. This restricts the search to to those results that fit the parameters. The evaluation method is as described below. The examination of the study contained data on the authors, publication dates, location, activities, and factors.

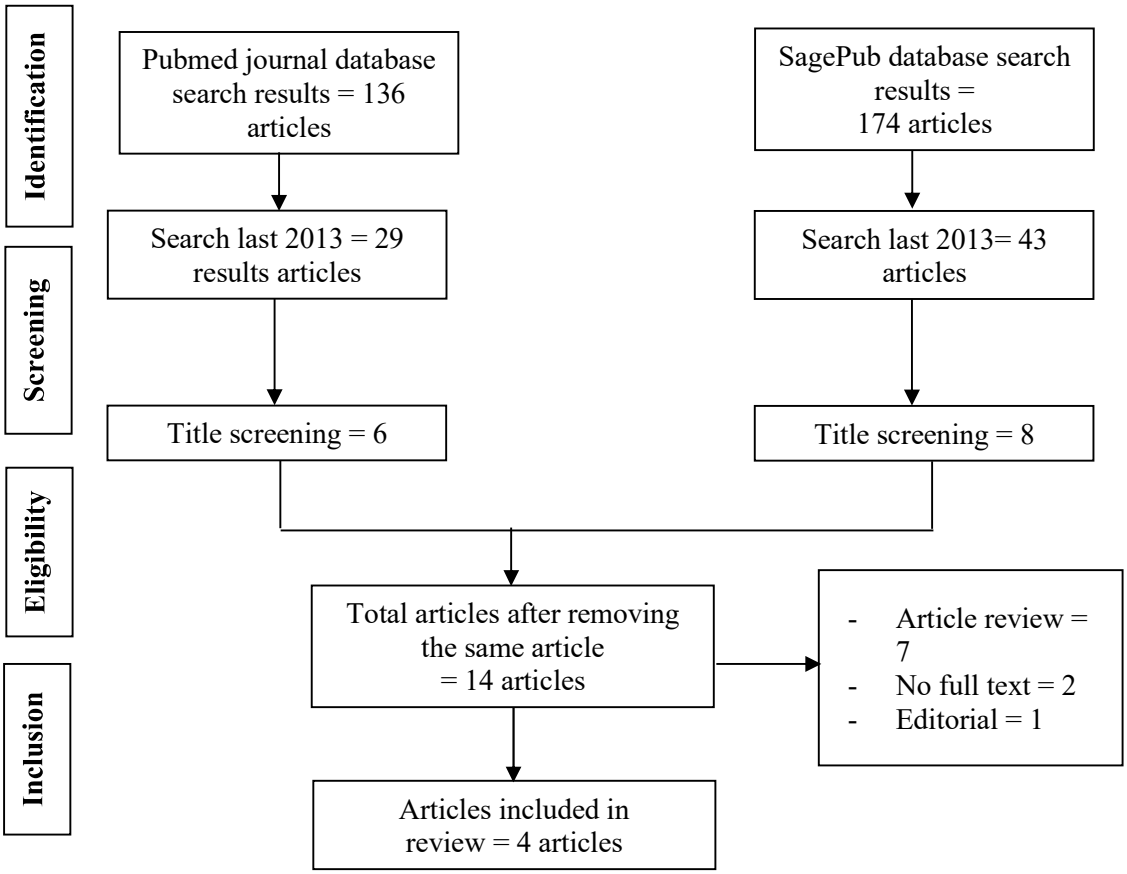

Figure 1. PRISMA search flowchart

After saving search results in EndNote, the database was purged of duplicate articles. Each article's title and abstract were examined by a pair of reviewers.Before picking which article to analyze, each author reviewed the publication's title and abstract. Then, we will examine all of the papers that meet the review's inclusion criteria. Following the completion of our inquiry, we will examine relevant research articles. This rule describes the types of papers that will be evaluated. It should be simpler to discern which objects warrant additional investigation. Which prior studies were incorporated into the review, and why?

RESULT

Deukmedjian, et al (2013)[5] conducted a study with scoliosis patients, 17 patients had category-specific surgery, while 10 had surgery outside their category. The average age was 61 and the mean follow-up was 17 months. CSVL, SVA, PT, and LL changed somewhat in the green and yellow groups, as did coronal Cobb angle (12° and 11°, respectively). VAS and ODI improved 35 and 17 points in the green group and 36 and 33 points in the yellow group. In the red subgroup, coronal Cobb angle decreased 22°, LL increased 15°, while PT and SVA changed little. Three patients in the yellow subgroup received "green" surgery and had a 17° coronal Cobb angle decrease, a 10° LL decrease, and 1.3 cm and 5° SVA and PT increases. Seven patients in the red group who underwent "yellow" or "green" surgery had a 16° reduction in coronal Cobb angle, 0.1 cm CSVL, 2.8 cm SVA, 4° PT, 28 points VAS, 12 points ODI, and 15° lumbar lordosis. One wound infection, two transient thigh numbnesses, and one transient groin pain occurred postoperatively.

Anand, et al (2013)[10] study showed patients undergoing same-day, single-stage surgery saw a mean blood loss of 412 mL and a mean operative duration of 291 minutes. Patients undergoing 2-stage surgery experienced an average blood loss of 314 mL and a surgical duration of 183 minutes for direct lateral interbody fusion and 357 mL and 243 minutes, respectively, for posterior instrumentation and axial lumbar interbody fusion. Mean hospitalization lasted 7.6 days (2-26 d). The average Cobb angle prior to surgery was 24.7° (8.3°-65°), which was corrected to 9.5° (0.6°-28.2°). The average preoperative Coronal balance was 25.5 millimeters, which was corrected to 11 millimeters.

Table 1. The litelature include in this study

Author	Origin	Method	Sample	Diagnosis	Procedure	Conclusion
Deukmedjian, 2013[5]	United State of America (USA)	Retrospective study	256 patients	Adult degenerative scoliosis	Minimally invasive lateral	The implementation of lateral minimally invasive methods for adult degenerative scoliosis requires careful patient selection. Patients with intact spinopelvic balance are candidates for isolated lateral interbody fusion with or without instrumentation. With advanced modifications of the lateral technique, such as anterior longitudinal ligament release, it is possible to treat moderate sagittal deformity (compensated by pelvic retroversion). The lateral technique may be utilized for anterior column support and to increase arthrodesis in individuals with severe deformity.
Anand, 2013[10]	United State of America (USA)	Cross sectional study	71 patients	Degenerative scoliosis (54), idiopathic scoliosis (11), and iatrogenic scoliosis	Direct lateral interbody fusion (66), axial lumbar interbody fusion (34), and posterior instrumentation (67)	A combination of three novel MIS techniques allows for comparable correction of adult spinal deformity, with low pseudarthrosis rates, significantly improved functional outcomes, and excellent clinical and radiological improvement. However, the morbidity and complication rates at early and long-term follow-up are significantly lower with the combination of these techniques.
Park, 2015[11]	USA	Retrospective, multicenter study	105 patients	ASD	circumferential MIS (cMIS) and hybrid (HYB) surgical approach	Decreased ODI and VAS pain scores indicate that both HYB and cMIS techniques resulted in clinical improvement. While there was no significant difference between groups in the degree of radiographic correction, the HYB group demonstrated larger absolute improvement in degree of lumbar coronal Cobb angle correction, increased LL, decreased SVA, and decreased LL-PI. However, the rate of complications was greater with the HYB technique than with the cMIS strategy.
Hua, 2020[12]	China	Retrospective study	112 consecutive patients	One-level lumbar spinal stenosis	Lumbar endoscopic unilateral laminotomy bilateral decompression (LE-ULBD) and minimally invasive surgery transforaminal lumbar interbody fusion (MIS-TLIF)	The one-level LSS that does not have degenerative spondylolisthesis or deformity can be treated successfully and safely with either the LE-ULBD or the MIS-TLIF procedure. In comparison to MIS-TLIF, the LE-ULBD procedure is less invasive and places less of a financial burden on the patient. For patients with one level of LSS who do not have degenerative spondylolisthesis or deformity, decompression plus instrumented fusion may not be required for treatment.

The average preoperative sagittal balance was 31.7 millimeters and was corrected to 10.7 millimeters. The average preoperative lumbar apical translation was 24 millimeters and was reduced to 12 millimeters. Fourteen patients suffered adverse outcomes necessitating intervention: four cases of pseudoarthrosis, four cases of persistent stenosis, one case of osteomyelitis, one case of adjacent segment discitis, one case of late wound infection, one case of proximal junctional kyphosis, one case of screw prominence, one case of idiopathic cerebral hemorrhage, and two cases of wound dehiscence.[10]

A study showed the mean Oswestry Disability Index (ODI) score improved by 30.6% and 25.7% in the HYB and cMIS groups, respectively, while the mean visual analog scale (VAS) scores for back/leg pain improved by 2.4/2.5 and 3.8/4.2, respectively. There was no significant difference in ODI or VAS ratings across groups. In the HYB group, the lumbar coronal Cobb angle reduced by 13.5°, the lumbar lordosis increased by 8.2°, the sagittal vertical axis decreased by 2.2 mm, and the LL-pelvic incidence mismatch decreased by 8.6°. Cobb angle lowered by 10.3°, LL improved by 3.0°, SVA increased by 2.1 mm, and LL-PI decreased by 2.2° in the cMIS group. There were no significant differences between groups in these radiographic characteristics. However, the rate of complications was greater in the HYB group (55%) than in the cMIS group (33%; $p = 0.024$).[11]

Hua, et al (2020)[12] study showed LE-ULBD had lower operation time, projected blood loss, time to ambulation, and hospital stay than MIS-TLIF. Both groups had considerably lower postoperative VAS and ODI scores. The modified Macnab criteria gave the two groups 90.6 and 93.8% excellent/good outcomes. Both groups had similar mean VAS, ODI, and modified Macnab results. LE-ULBD had cheaper healthcare than MIS-TLIF. LE-ULBD had two intraoperative epineurium injuries. LE-ULBD had one cauda equina damage. MIS-TLIF did not cause nerve, dural, or cauda equina syndrome. One MIS-TLIF patient had transitory urine retention, pleural effusion, incision infection, and implant dislodgement.

DISCUSSION

Progressive and painful thoracolumbar and lumbar adult spinal deformity is frequently treated surgically with long posterior fusions from the thoracic spine to the pelvis, especially when there is a significant thoracic curve component. In the majority of cases, pedicle screws and rods are used.[13] Additionally, its usage in the treatment of degenerative diseases, injuries, and malignancies has gained popularity. Earlier fastening techniques utilized hooks and wires. However, pedicle screw instrumentation offers a more firm fixation. Instrumentation serves to correct spinal deformities or stabilize the spine in order to facilitate biological fusion. Surgeons can achieve favorable outcomes by knowing the available technology, the biological restrictions, and the intended solution.[14]

Adult degenerative scoliosis refers to a variety of spine deformities caused by a lack of sagittal, coronal, and axial equilibrium. In this heterogeneous patient population, the surgeon who corrects the abnormality must be prepared to perform both minimally invasive and traditional open surgical repair. MIS procedures have been shown in numerous studies to lower costs, preserve postoperative muscle mass, reduce physiological stress on the patient, and improve perioperative problems such as blood loss, infection, and narcotic use.[15–17]

Percutaneous pedicle screws, anterolateral approaches, specialized instrumentation for deformity correction, improved imaging, and bone morphogenetic protein have all played important roles in allowing spine surgeons to manage these complex pathologies in a manner that is minimally invasive. Neuromonitoring is another important tool that has been developed. In spite of this, the ability to provide correction with minimally invasive surgery therapy of spinal deformity is limited in comparison to what can be provided by normal open procedures.[15–17]

In general, the MIS approaches described in the research fell into two categories: anterior column support and posterior instrumentation. The anterior column, discectomy, and interbody fusion were performed utilizing a variation of a minimally invasive far lateral technique. Extreme lateral interbody fusion (XLIF) and direct lateral interbody fusion (DLIF) are examples. For patient with uncompensated and minimal sagittal and coronal imbalance, stand alone or limited segmental lateral interbody fusion with posterior fixation at curve apex should be adequate. For more severe deformity, a hybrid MIS-open procedure will be needed. Three trials incorporated hyperlordotic cages to MIS lateral interbody fusion to increase treatment of sagittal deformity and restore lumbar lordosis with or without the use of an anterior longitudinal ligament release.[5,18]

The lumbosacral junction is inaccessible via a far lateral approach due to anatomical restrictions, necessitating the employment of an alternative technique. In various investigations, three MIS procedures were utilized either primarily or alternately for interbody fusion at the lumbosacral junction and, in certain circumstances, at L4-5. AxialLIF®, minimally invasive transforaminal lumbar interbody fusion (TLIF), and anterior lumbar interbody fusion are examples. Except for one study that utilized lateral plates, instrumentation consisted exclusively of posterior percutaneous pedicle screw fixation. Percutaneous screw fixation of the ilium has been utilized in select patients. Notably, a number of studies included patients who were treated with interbody fusions without extra apparatus.[19,20]

Clinical improvement was seen with both the HYB and cMIS treatments, as evidenced by lower ODI and VAS pain levels. While there was no statistically significant difference in radiographic correction between groups, the HYB group showed

larger absolute improvement in lumbar coronal Cobb angle correction, increased LL, decreased SVA, and decreased LL-PI. The HYB technique, on the other hand, has a greater complication rate than the cMIS strategy.[11] According to the findings of a study conducted by Anand and colleagues, the incidence of problems was comparatively low. The overall incidence of difficulties, which included both medical and surgical issues, was 22.9%.[10]

Due to the small size of the cohort and the novelty of some of the procedures, it is possible that certain potential issues were not discovered. For instance, advanced procedures such as anterior longitudinal ligament release pose a discernible risk of great vessel injury,[18] although none have been observed. In deformity surgery, the protection of brain structures is of fundamental importance. A 14.3% neurologic complication rate appears excessive at first glance. The majority of these, however, are temporary and related to the lateral approach. A comprehensive understanding of the architecture of the lumbar plexus and the use of continuous electromyographic neuromonitoring should aid to reduce the incidence of these approach-related problems. The decrease of perioperative complications in a population predisposed to comorbidity is one of the goals of MIS treatment. Only Isaacs et al. showed that 28.3% of patients had at least one comorbid condition prior to surgery.[21]

CONCLUSION

This study encompasses the variations of minimally invasive lateral technique utilized in the anterior approach, as well as the posterior approach with or without osteotomy. Surgeons have to be prepared to offer both open or MIS for patients. Various MIS technique and its combination including hybrid surgery are used in cases of adult spinal deformity, the appropriate technique chosen for the surgery should include factors such as the spinopelvic harmony, age and outcome prediction of each patients into consideration as each technique has its own advantages and disadvantages.

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