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Cost-Effectiveness of Adult Spinal Deformity Surgery

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Abstract

Study Design: Review article.

Objective: A review of the literature evaluating the cost-effectiveness of undergoing adult spinal deformity surgery and potential avenues for reducing costs.

Methods: A review of the current literature and synthesis of data to provide an update on the cost effectiveness of undergoing adult spinal deformity surgery.

Results: Compared with nonoperative management, operative management for adult spinal deformity is associated with improved patient-reported outcomes and quality of life; however, it is associated with significant financial and resource use.

Conclusion: Operative management for adult spinal deformity has been shown to be effective but is associated with significant cost and resource utilization. The optimal operative treatment is highly dependent on the patients' symptomatology and is surgeon dependent. Maximizing preoperative surgical health and minimizing postoperative complications are key measures in reducing the cost and resource utilization of adult spinal deformity surgery. Future studies are needed to evaluate how to optimize the cost-effectiveness.

Keywords

adult, spine, spinal deformity, cost-effectiveness

Introduction

Adult spinal deformity (ASD) results in significant pain, disability and diminished quality of life. Adults with scoliosis have reported worse health-related quality of life (HRQoL) outcomes, functional limitations, increased analgesic consumption, and increased incidence of back pain compared to those without scoliosis.[1] As the elderly population continues to grow, spine surgeons can expect an increasing demand for treating patients with spinal deformity. In patients older than 60 years, the prevalence of spinal deformity is reported to be as high as 68%, with a substantial impact on quality of life. Nonetheless, between the expanding elderly population and the increase in spinal fusion procedures being performed, the prevalence of ASD will continue to rise and presents a considerable financial burden on the health care system.[2,3]

In value-based health care, an evidence-based approach to the treatment of ASD requires examination of clinical outcomes, risks, costs, and methods for quality improvement. Multiple factors contribute to the decision-making process in undertaking ASD surgery. However, the application of cost-effective spinal deformity care is not well understood. Substantial dynamics exist in the operative and nonoperative approaches to ASD among surgeons. When operative intervention is indicated, treatment often entails a lengthy surgery associated with significant cost and resource utilization. Operative decisions regarding the optimal approaches often vary. Yet, the ideal surgical treatment optimizes clinical outcome while decreasing procedural risks and cost.

The annual expenditure for spinal care is estimated to be over $86 billion in the United States, with complex surgery

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performed for ASD being a significant contributor.[4] Therefore, it is imperative the practicing spinal deformity surgeon is cognizant of the clinical effectiveness of the operative intervention chosen. Understanding the degree of resource consumption and cost-effectiveness of corrective surgery over the course of the patient's overall care is imperative. In an era of rising health care costs and potential increase in adult spinal deformity surgery needs, determining significant cost drivers in surgical management is a crucial step in the process of increasing sustainability and cost-effectiveness of adult spinal deformity surgery. The purpose of this article is to critically evaluate the cost-effectiveness in ASD surgery, discuss potential cost mitigators, and provide a basis for future economic awareness in ASD.

Costs, Value, and Management of Adult Spinal Deformity

Spine-related care is a significant contributor to the annual health care expenditure and accounted for an estimated $90 billion in 2012.[5] Regarding ASD care and providing cost-effective treatment, both nonoperative and operative treatment for ASD are associated with significant cost. To better understand the value of nonoperative management, Glassman et al[6] investigated nonoperative resource use and associated cost of treatment during an observational 2-year period in patients with adult scoliosis. The mean cost of treatment was $14 0222 and $9704 for the high and low symptom groups, without significant change in HRQoL. In a subsequent analysis, Glassman et al[7] estimated the mean nonoperative care cost to be $10 815 per patient for a 2-year treatment period without reported improvement. Existing literature has shown nonoperative management for ASD to be both expensive and ineffective.

In contrast, surgical treatment has been shown to be associated with improved outcomes but involves significant cost and resource utilization. The expense associated with ASD surgery is estimated to be as high as $103 143 per surgical procedure.[8] Smith et al[9] retrospectively reviewed a prospectively collected, multicenter database of adults with spinal deformity over a 2-year period who underwent operative versus nonoperative treatment for adult scoliosis. The authors concluded that despite having significantly greater numeric rating scale (NRS) and Oswestry Disability Index (ODI) scores, and lower Scoliosis Research Society (SRS-22) scores, surgically treated patients exhibited significantly less back pain, disability, and improved health status compared with nonoperatively treated patients.[9] Further literature supports the benefits of surgical treatment for ASD and is associated with improvement in pain, HRQoL, and patient satisfaction.[10,11]

Scheer et al[12] performed a retrospective review of a prospective multicenter database evaluating the quality-adjusted life years (QALYs) between operative and nonoperative treatments for ASD patients. A total of 479 patients were analyzed (operative, 258; nonoperative, 221) with health utility values calculated from Short Form–6 Domains (SF-6D) scores and were used to calculate QALYs at 1-, 2-, and 3-year follow-up with propensity score matching. At 2 years, operative treatment had larger QALYs gained (from baseline) (0.112 ± 0.243 vs 0.008 ± 0.195, $P < .01$). In a subanalysis for patients who completed 1 to 3 years of follow-up, operative treatment had significantly larger QALYs gained at 1, 2, and 3 years compared with the nonoperative cohort, indicating the superiority of operative treatment in the management of ASD: 1 year (0.073 ± 0.121 vs 0.029 ± 0.082, $P = .0447$), 2 years (0.167 ± 0.232 vs 0.036 ± 0.173, $P = .0030$), and 3 years (0.238 ± 0.379 vs 0.059 ± 0.258, $P < .01$).[12]

Operative management of ASD has repeatedly demonstrated improvements in HRQoL, yet there is a subset of patients that may benefit from nonoperative measures. In the absence of significant or progressive neurologic deficits and deformity progression, nonoperative treatment modalities should be explored. However, the utilization of nonoperative management in patients who will ultimately require deformity surgery can be a means of ineffective medical care and a resource drain on the health system. Characterizing patients with ASD who will likely proceed for operative treatment from nonoperative management may allow for more efficient cost savings and resource allocation. Passias and colleagues[13] proposed patient profiling at initial consultation in order to identify patients with ASD at risk for needing operative management from initial nonoperative treatment to reduce ineffective ASD management. The authors analyzed a total of 510 patients who were grouped into 3 cohorts (nonoperative, operative, and crossover) and evaluated the factors influencing the conversion to operative treatment compared to those who remained nonoperative and those who initially chose surgery. The authors found nonoperative patients with Schwab T/L/D curves and ODI $\geq$ 40 (odds ratio [OR] 3.05, $P = .031$), and with high pelvic incidence $-$ lumbar lordosis (PI-LL) modifier grades ("+"/"++") and ODI $\geq$ 40 (OR 5.57, $P = .007$) showed increased crossover risk. What they also found was that crossover patients achieved similar 2-year outcomes as the initial operative group, further supporting the growing evidence that operative intervention for ASD is effective. Identification of these factors at the initiation of treatment is important to analyze as costs associated with nonoperative care can be reduced and lead to improved outcomes and QALYs.[13]

Analysis of Cost in Adult Spinal Deformity Surgery

Evaluating potential cost-drivers of ASD surgery and avenues to reduce the costs associated with surgical intervention and resource utilization in the preoperative, operative, and perioperative intervals require careful consideration. In 2018, Stephens and colleagues[14] performed a single-center prospective longitudinal registry study of 129 patients undergoing elective spine surgery for thoracolumbar deformity and evaluated cost drivers associated with surgical management during the operative and 3-month postoperative period. Results were in agreement with prior literature showing a significant improvement ($P < .001$) in patient-reported outcomes, including ODI, Numeric Rating Scale for Back Pain (NRS-BP), Numeric Rating Scale for Leg Pain (NRS-LP), and quality of life (Euro-Qol-5D). Furthermore, the authors found that patient comorbidities, including chronic obstructive pulmonary disease ($P = .009$), diabetes ($P = .025$), preoperative deformity diagnosis ($P = .046$), number of levels involved ($P = .016$), length of surgery ($P = .031$), hospital stay ($P = .044$), 90-day readmission ($P = .021$) and use of inpatient rehabilitation ($P < .0001$) significantly contributed to the cost of ASD surgery.[14]

Yagi et al[15] evaluated the impact of advanced age on the clinical outcomes and cost-effectiveness of ASD surgery using a multicentered retrospective database. Patients were grouped by age, 50 to 64 years or >70 years, and were propensity score–matched for sex, body mass index, upper and lower instrumented vertebrae, the use of pedicle subtraction osteotomy, and sagittal alignment. Results showed ODI and SRS-22 pain and self-image were significantly inferior in the older age group at 2-year follow-up (ODI 32% ± 9% vs 25% ± 13%, $P = .01$; SRS-22 pain 3.5 ± 0.7 vs 3.9 ± 0.6, $P = .05$; SRS-22 self-image 3.5 ± 0.6 vs 3.8 ± 0.9, $P = .03$). Additionally, the older group had more complications than the middle-aged group (55% vs 29%), with an odds ratio of 4.0 for postoperative complications (95% CI 1.1-12.3) and 4.9 for implant-related complications (95% CI 1.2- 21.1). Cost-utility analysis at 2 years following surgery revealed that deformity corrective surgery was less cost-effective in the older group (cost/QALY: older group $211 636 vs middle-aged group 125 887, $P = .01$).[15]

ASD surgery can be associated with substantial blood loss, resulting in prolonged operative time and requiring blood transfusion products. Gandhoke et al[16] conducted an observational cohort study evaluating the cost-effectiveness of radio frequency hemostatic sealer (RFHS) versus traditional hemostasis with bipolar electrocautery. Patients were matched for blood loss–related variables, including total hospital expenses for FRHS, laboratory expenses, and blood transfusions. Multivariable linear regression models showed that estimated blood loss (EBL) was a significant independent predictor of transfusion requirements in both groups. Mean EBL was greater in the control group (2201 vs 1416 mL, $P = .0099$), and the number of transfusions was also greater (14.5 vs 6.5, $P = .0008$). Cost-effectiveness analysis demonstrated that utilization of RFHS cost $108 more (compared to without using RFHS) to avoid 1 unit of blood transfusion, making RFHS a reasonable cost-effective choice in ASD surgery to avoid prolonged operative time and blood loss.[16]

Another controversial perioperative intervention that may affect cost savings is the use of tranexamic acid (TXA). TXA is used to decrease the need for blood transfusions, with the secondary result of decreased total care costs. Recently, in 2020, Ehresman and colleagues[17] performed a retrospective review on patients who underwent elective lumbar or thoracolumbar surgery for degenerative joint disease (DJD) either receiving TXA or not. They reviewed outcomes such as intraoperative blood loss, use of packed red blood cells (PRBC), and hemostasis costs. Overall, use of TXA was not found to have a significant impact on cost savings, despite the significantly decreased mean intraoperative blood loss difference between the 2 groups (1039 vs 1437 mL, $P = .01$). However, on subgroup analysis, they found that there was a significant net cost savings of $328.69 when using TXA when more than 4 vertebral levels were involved in the construct. Through extensive literature review, there have been multiple studies analyzing the use of TXA in ASD surgeries; however, we could find none that have assessed its impact on total cost, and thus no guidance can be offered regarding their efficacy in surgery for ASD.[17]

The off-label use of recombinant human bone morphogenetic protein (rh-BMP) has continued to be a topic of interest when considering cost analysis for ASD. The use of BMP is common in surgery for thoracolumbar ASD, as its use has been shown to increase fusion rates. and subsequently reducing total related costs despite the high upfront expenses of its use. Yet, there has been limited literature discussing BMP's cost-benefits in ASD, and whether the potential reduction in pseudarthrosis rates outweighs its cost. In 2019, Safaee et al[18] performed a single-center retrospective review to determine the cost-effectiveness between use of BMP and the prevention of pseudarthrosis in ASD. 151 patients with ASD underwent instrumented fusion from 2010 to 2016 with a mean follow-up of 23 months. BMP was used in 98 cases. Of the 53 patients where BMP was not utilized, 9 developed pseudarthrosis requiring revisional surgery. Of the 98 patients where BMP was utilized, 6 developed pseudarthrosis requiring revisional surgery. This accounted for an 11% absolute risk reduction (ARR) and a number needed to treat (NNT) of 9.2. The mean cost of BMP was found to be $10 444 with a standard deviation (SD) of $4607. The mean direct and total costs with similar controls between the surgeries with/without BMP were found to be significantly different (total cost with BMP = $147 428 ± 27 048, total cost with no BMP = $130 961 ± 37 673, $P = .008$). The mean direct and total revisional costs were not found to be significantly different between the 2 groups (BMP = $81 278 ± 32 822, no BMP $85 644 ± 52 992, $P = .862$). However, nonhospital costs such as rehabilitation and outpatient care were not included in the analysis. With a NNT of 9.2 and the mean cost of BMP estimated at $10 444, it was estimated that approximately $96 181 would be expended to prevent 1 case of pseudarthrosis requiring revision. After extrapolation, accounting for decreased reoperation rate with BMP and variations in cost of BMP, the study determined that in order for BMP to be cost neutral in the long-term for total in-hospital costs, it would have to be priced at $5663. With the limitation that the study did not include the nonhospital costs associated with reoperation, the cost-benefit of BMP was undervalued, and further analysis is required to evaluate the total related costs involved.[18]

Advancements in minimally invasive surgery (MIS) have established the controversy on whether MIS techniques, as opposed to traditional open methods, will affect cost factors. These factors may include intraoperative resources used, postoperative complications, decreased blood loss, readmission rates, hospital length of stay (LOS), and postoperative rehabilitation requirements/costs. Studies on MIS cases for spondylosis have demonstrated decreased total hospital costs and LOS

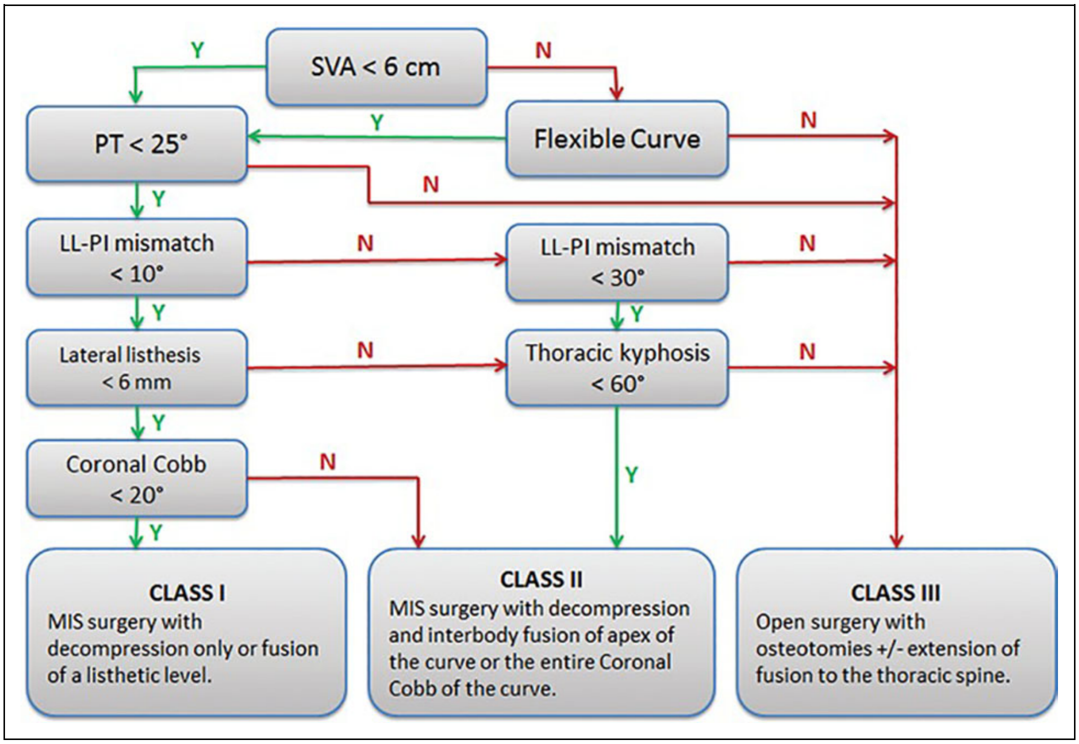

Figure 1. Minimally invasive spinal deformity algorithm.

when compared with open procedures for 1- and 2-level surgeries.[19] However, limited literature has been published on the cost-benefits of MIS for ASD. In 2015, Uddin and colleagues[20] established the first study to evaluate the cost of MIS for correction of adult degenerative scoliosis. The study comprised a retrospective review from 2006 to 2012 where 71 patients underwent either a minimally invasive lateral lumbar interbody fusion or transforaminal lumbar interbody fusion with subsequent percutaneous posterior instrumentation (N = 38) or a posterior midline open approach (N = 33). MIS and open study groups had an average of 4.37 and 7.61 levels of fusion, respectively ($P < .01$). Multiple outcomes were evaluated, including total inpatient cost, LOS, EBL, pre- and postradiographic measurements, as well as functional scores, including the ODI and visual analogue scale (VAS). Differences after statistical analysis showed an average savings of \$122 081.71 in inpatient hospital costs with MIS when compared with open surgery (mean inpatient cost for MIS = \$269 807.35, open = \$391 889.05, $P < .01$). These average inpatient totals include the associated costs of complications and revision surgeries; however, the values of these additional surgeries were not numerically stated. Inpatient hospital LOS (including revision surgeries) was also determined to be significantly lower for the MIS cohort with a mean of 7.03 days when compared with the open group with a mean of 14.88 days ($P < .01$). Mean EBL was found to be 470 mL for the MIS group and 2872 mL for the open group ($P < .01$). Outpatient rehabilitation LOS and total cost were found to be comparable with no statistically significant difference ($P = .48$). When comparing intra- and postoperative complications, the MIS cohort demonstrated decreased dural tears, rod fractures, and infection rates. However, it was found that the MIS cohort required twice as many revisional surgeries when compared with the open cohort (MIS N = 10, open N = 5). Reasons for revision included pseudarthrosis, fractured pedicle screws, and cage migration. Functional and mechanical outcomes were also inferior in the MIS group when compared with the open group. The net change in sagittal vertical axis (SVA) correction was found to be greater in the open surgical group (MIS = −11.97 mm, open = −43.19 mm, $P = .05$). As mentioned, the average level of fusions between the groups was significantly different (MIS N = 4.37, open N = 7.61), which would influence the total costs of the procedure and functional outcomes. Overall, it was determined that MIS may decrease costs for patients with less severe preoperative SVA. However, it should not necessarily be used for cost purposes in patients with more severe preoperative SVA due to the superior amount of SVA correction that open surgery may provide.[20] To help with the surgeon's choice of approach, in 2013, Mummaneni et al[21] created a multifactorial treatment algorithm when determining whether or not to use MIS techniques for ASD correction. The algorithm is based on multiple factors, including SVA, pelvic tilt angle, length of lateral listhesis, coronal Cobb angle, lumbar lordosis, pelvic incidence, and degree of thoracic kyphosis. Based on these variables, the patient is placed into 1 of 3 classes as shown in Figure 1 (minimally invasive spinal deformity algorithm).[21] The study recommends that minimally invasive surgery with decompression or fusion of a listhetic level be done for class I deformities. For class II deformities, MIS should be attempted with decompression and interbody fusion at the apex of the curve or the entire coronal Cobb of the curve. For class III deformities, open surgery with osteotomies and potential extension of the fusion to the thoracic spine should be pursued.[21]

Unplanned reoperation following the initial spinal deformity corrective procedure is associated with additional surgical risk, increased cost and resource use, and diminished cost-effectiveness of the intervention. Crawford et al[22] reported on the prevalence and indications for unplanned reoperations following index surgery in the adult symptomatic lumbar scoliosis National Institutes of Health–sponsored clinical trial, which evaluated 153 patients who underwent adult spinal deformity surgery as part of an observational, randomized, or crossover groups with 2-year follow-up. Results demonstrated 32 patients (24%) required an unplanned reoperation; a total of 45 reoperations were performed in 37 patients. Analysis showed 11 patients (7%) underwent reoperation within 90 days of the index surgery; 2 for superficial wound dehiscence, 3 for radiculopathy with screw removal, and 6 for acute proximal junctional failure (PJF). Overall, the most common indication for reoperation was rod fracture/pseudarthrosis accounting for 62% (28/45) of reoperations. PJF was the second most common indication for reoperation and constituted 22% (10/45) of the reoperations.[22] Interestingly, Safaee et al[23] performed a retrospective review of 195 patients who underwent adult spinal deformity surgery and analyzed the cost-effectiveness of prevention strategies to mitigate PJF. Of 195 patients, 135 (69%) were female. Ligament augmentation was used in 99 cases (51%), hook fixation in 60 cases (31%), and vertebroplasty in 71 patients (36%). PJF occurred in 18 cases (9%) with rates of PJF lower in the ligament augmentation group (4% vs 15%, $P = .011$). Both univariate and multivariate analyses found that ligament augmentation showed a significant association with PJF reduction (OR 0.196, 95% CI 0.050-0.774; $P = .020$). The authors performed a cost-benefit analysis for ligament augmentation by comparing the cost of ligamentum augmentation in the index case ($1100) versus the cost of reoperation for PJF ($119 217). Given a 10.5% reduction in the rate of PJF with ligament augmentation in their cohort, the authors calculated an NNT of 9.5 patients to prevent 1 operation. Identifying which patients are at greatest risk of developing PJF and requiring reoperation is imperative to selecting for ligament augmentation and performing a cost-effective surgery.[23]

Conclusion

Adults with painful and disabling spinal deformity have been shown to benefit from surgical treatment compared with nonsurgical treatment. Although nonoperative management is the initial treatment modality, it is not cost-effective and has not shown to have a positive impact on QoL. On the contrary, there is convincing evidence surgical treatment for ASD is effective and improves QoL. Strides must be made to identify patient-related factors, such as existing medical comorbidities and severity of spinal deformity, along with identifying perioperative factors that can potentially result in increased cost accumulation or mitigation as this can provide hospitals with prospective aims for improving cost-effectiveness and sustainability in adult spinal deformity surgery.

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