






# Is Less Really More? Economic Evaluation of Minimally Invasive Surgery

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## Abstract

**Study Design:** Review.

**Objective:** A comparative overview of cost-effectiveness between minimally invasive versus and equivalent open spinal surgeries.

**Methods:** A literature search using PubMed was performed to identify articles of interest. To maximize the capture of studies in our initial search, we combined variants of the terms “cost,” “minimally invasive,” “spine,” “spinal fusion,” “decompression” as either keywords or MeSH terms. PearlDiver database was queried for open and minimally invasive surgery (MIS; endoscopic or percutaneous) reimbursements between Q3 2015 and Q2 2018.

**Results:** In general, MIS techniques appeared to decrease blood loss, shorten hospital lengths of stay, mitigate complications, decrease perioperative pain, and enable quicker return to daily activities when compared to equivalent open surgical techniques. With regard to cost, primarily as a result of these latter benefits, MIS was associated with lower costs of care when compared to equivalent open techniques. However, cost reporting was sparse, and relevant methodology was inconsistent throughout the spine literature. Within the PearlDiver data sets, MIS approaches had lower reimbursements than open approaches for both lumbar posterior fusion and discectomy.

**Conclusions:** Current data suggests that overall cost-savings may be incurred with use of MIS techniques. However, data reporting on costs lacks in uniformity, making it difficult to formulate any firm conclusions regarding any incremental improvements in cost-effectiveness that may be incurred when utilizing MIS techniques when compared to equivalent open techniques.

## Keywords

minimally invasive, cost, spine surgery, TLIF, deformity, discectomy

## Introduction

Health care in the United States accounts for 18% of its gross domestic product, approximately twice as much as other high-income countries.<sup>1</sup> A significant contributor to this economic load is spine-related health care expenditures.<sup>2</sup> Out of necessity, implementation of bundled payments has led to the coordination of patient care among hospitals and surgeons with a greater emphasis on improving both quality of care and cost-efficiency.<sup>3</sup>

Recent advancements in techniques and instrumentation have further increased the utilization of minimally invasive surgical techniques by expanding indications to include decompression, fusion, trauma, deformity, and oncology.<sup>4</sup> Initial reports found that minimally invasive surgery (MIS) had a

higher upfront cost for implants and equipment.<sup>5</sup> As a result of a steep associated learning curve, higher initial operative times also made MIS appear to be more expensive than equivalent open surgeries.<sup>6</sup> However, recent literature suggests that MIS may actually offset these higher costs by lowering complications, infections, hospital length of stay (LOS), estimated blood loss (EBL), and recovery time.<sup>5,7-11</sup>

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In the era of the opioid epidemic, MIS can also further mitigate costs by decreasing approach-related morbidity, postoperative pain, and subsequent opioid demand. The economic burden of prescription opioid overdose, abuse, and dependence in the United States was estimated to be \$78.5 billion in 2013.<sup>12</sup> Numerous studies have demonstrated a significant decrease in postoperative pain using MIS techniques.<sup>13,14</sup> In this context, significant advancements in postoperative pain management protocols have helped further drive down costs associated with surgical episodes of care by enabling many MIS spine procedures to be performed in an outpatient setting.<sup>15</sup>

While a fair number of studies have evaluated the cost-effectiveness of MIS, definitive conclusions regarding the economic value of MIS cannot be made given the significant variability in cost comparison methodologies.<sup>16</sup> Therefore, the primary objective of this study is to serve as a comparative overview of cost-effectiveness between minimally invasive versus equivalent open spinal surgeries. Secondarily, a brief comparative overview of clinical outcomes between minimally invasive versus open spinal surgical outcomes is offered.

## Methods

A literature search using PubMed was performed to identify articles of interest. To maximize the capture of studies in our initial search, we combined variants of the terms “cost,” “minimally invasive,” “spine,” “spinal fusion,” “decompression,” “deformity,” “discectomy,” “trauma,” “tumor” as either keywords or MeSH terms. All retrieved articles were then further reviewed to match our inclusion and exclusion criteria. We included all clinical studies evaluating minimally invasive and comparative open surgical spine outcomes. We excluded all basic science and animal studies. In addition to cost analyses performed, additional attention was paid to study design, indication for surgery, surgical intervention, sample size, age, operative time, blood loss, perioperative complications, and LOS.

Additionally, we assessed reimbursement costs using commercially available data sets. Costs of open and minimally invasive (endoscopic and percutaneous) surgery were compared using the PearlDiver online health care database ([www.pearldiverinc.com](http://www.pearldiverinc.com)) to analyze Mariner all payer claims dataset. Using the Classification of Diseases, Tenth Revisions (ICD-10), procedure codes between Quarter 3 of 2015 and Quarter 1 of 2017, patients were queried and grouped based upon their surgery (open fusion, MIS fusion, open discectomy, MIS discectomy), anterior or posterior approach, and whether the surgery was single or multi-level. Within each surgical group, patients with outlier costs were excluded so that only patients comprising the range between the 25th and 75th percentiles were analyzed. Averages and standard deviations of the insurance reimbursement rates were then analyzed for each surgical group. Total reimbursements for 2016 for each surgical group were reported as well. Due to the PearlDiver policy, groups with less than 11 patients were excluded. *T*-test was used to calculate significant differences between open and MIS groups with  $P < .05$  being significant.

## Results

### Lumbar Stenosis

Minimally invasive lumbar decompression for the treatment of symptomatic lumbar stenosis has been shown to be equivalent to, and in some aspects, superior to equivalent open approaches.<sup>17-19</sup> In regard to cost-effectiveness, Parker et al conducted a 2-year cost utility study on open versus MIS multilevel hemilaminectomy for the treatment of symptomatic lumbar stenosis.<sup>20</sup> Open technique involved the use of a subperiosteal dissection via a midline approach, while the MIS approach utilized tubular retractors via a paramedian approach. A total of 54 patients (27 open vs 27 MIS) were included in the study. All patients had multilevel ( $\geq 2$ ) pathology, with 42 (78%) patients undergoing a 2-level decompression and 12 (22%) patients undergoing a 3-level decompression. Clinical outcomes were measured via visual analogue scale (VAS) scores for low back pain, VAS scores for leg pain, Oswestry Disability Index (ODI) scores, Shor Form (SF)-12 physical and mental component scores, and EQ-5D scores, while treatment effectiveness was measured via quality-adjusted life years (QALYs). Ultimately, patients in both cohorts improved significantly when compared to preoperative scores. Both open and MIS laminectomy were associated with a cumulative gain of 0.72 QALYs 2 years after surgery. Total 2-year mean cost for open hemilaminectomy was \$25 420 (95% confidence interval: \$25 389 to 25 450) versus \$23 109 (95% confidence interval: \$23 078 to 23 140) for the MIS approach ( $P = .21$ ). Both groups had similar resource utilization (ie, outpatient visits, spine-related diagnostic tests, injections, assist devices, emergency room visits, and rehabilitation or nursing facility days). Ultimately, they concluded that MIS multilevel hemilaminectomy is associated with similar cost over 2 years when compared to a traditional open approach.

Knight et al compared outcomes and cost utilization in open versus MIS approaches to lumbar stenosis as well in a group of 104 patients.<sup>21</sup> Thirty-eight (37%) patients underwent open decompression while 66 (63%) underwent MIS decompression. This study analyzed single-level decompression in addition to multilevel surgery, with no significant difference in number of levels decompressed in both groups. Consistent with prior studies, there was no significant difference in clinical outcomes between the 2 groups. In terms of cost analysis, this study analyzed the median cost per procedure type for Medicare patients only by looking at median operation room time cost and median LOS cost. For stenosis patients, median cost for open procedures was significantly higher compared to a tubular approach (\$7305 vs \$4518,  $P < .0001$ ). In this study, as a result of shorter operation room times and LOS, the direct cost of an MIS approach to lumbar stenosis appears to be significantly lower than that of an open approach.

### Lumbar Discectomy

One cost-utility study from the Netherlands specifically examined open versus MIS tubular approaches to lumbar disc

herniations.<sup>22</sup> Patients (n = 325) were randomized into either an open or MIS cohort. There were no significant differences in outcome scores across all measured variables. There was also no significant difference in QALYs between the 2 groups. The average cost of initial surgery was \$226 higher in the tubular microdiscectomy group than the open group (\$2908 vs \$2682,  $P = .02$ ). Total health care costs, including postoperative visits, physical therapy, home care, and medications, were also higher by \$460 in the tubular microdiscectomy group (\$5529 vs \$5070,  $P = .20$ ) though this was not significant. The authors also compared total non-health care costs, including loss of productivity, domestic help, informal care, and out-of-pocket expenses, and found a difference of \$1032 in favor of open microdiscectomy versus MIS (\$11 329 vs \$10 297,  $P = .42$ ). Overall, the authors conclude that MIS microdiscectomy is not likely to be cost-effective when compared to an open approach.

The cost-effectiveness of percutaneous and endoscopic discectomy has also been demonstrated in the literature.<sup>23,24</sup> In their retrospective analyses of 456 patients surgically managed for lumbar disc herniations, Choi et al found that endoscopic lumbar discectomy (regardless of technique) was associated with a cost savings of \$8064 per QALY when compared to traditional microdiscectomy.<sup>23</sup> A noninferiority randomized controlled trial comparing the effectiveness and cost-effectiveness of percutaneous transforaminal endoscopy versus open discectomy is also currently underway.<sup>25</sup>

### Transforaminal Lumbar Interbody Fusion

The most commonly published topic regarding cost-effectiveness in MIS versus open surgery is for transforaminal lumbar interbody fusion (TLIF). Five separate studies from 2012 to 2015 conducted a treatment outcomes and cost analysis of open versus MIS TLIF. All studies demonstrated cost savings for MIS TLIF when compared to open TLIF, though not all differences reached statistical significance. Total savings, which accounted for direct hospital costs in addition to indirect costs which account for productivity loss, ranged from \$3569 to \$9295 per patient,<sup>16,26-28</sup> while direct hospital costs ranged from \$1758 to \$2820 per patient.<sup>11,16,26-28</sup> In general, patient outcomes were reported to be similar,<sup>26-28</sup> though in Singh et al, patients who had undergone MIS TLIF had a significantly lower 6-month postoperative VAS score when compared to their open counterparts.<sup>29</sup> Multiple studies reported significant differences in surgical time, anesthesia time, and EBL, as well as LOS in favor of MIS TLIF versus open.<sup>11,26-29</sup>

Additionally, Parker et al examined the risk of surgical site infections (SSIs) in MIS versus open TLIF and concluded that open procedures are associated with a higher risk of SSIs (0.6% vs 4.0%,  $P = .0005$ ).<sup>10</sup> The mean hospital cost associated with treatment of postoperative SSI following TLIF was calculated to be \$29 110. The 3.4% decrease in reported incidence of SSI in MIS versus open TLIF corresponds to a direct cost savings of \$98 974 per 100 MIS TLIF procedures performed.

### Trauma/Fracture

We identified 10 articles comparing open and MIS approaches for treating spinal trauma/fractures. Seven of these studies found that MIS was significantly favorable with respect to operative time,<sup>30-36</sup> and the remaining 3 studies<sup>37-39</sup> found no significant difference between MIS and open surgical approaches. Eight studies evaluated intraoperative blood loss, and all 8 studies found that MIS techniques resulted in significantly less blood loss.<sup>32,34-40</sup> Of the 6 studies that reported results on LOS, 3 studies found MIS to be the favorable technique<sup>30,31,36</sup> and 3 studies did not find any significant differences<sup>32,34,37</sup> between MIS and open. Only one Chinese group reported data on costs. In their retrospective cohort study comparing MIS (18 patients) versus a Wiltse approach (21 patients) to fixation of mono-segmental thoracolumbar fractures, Dong et al found that the Wiltse approach resulted in lower total costs when accounting for hospitalization charges and implants used when compared to MIS (open approach  $4.23 \pm 0.93$  compared to MIS  $5.31 \pm 0.47$ ; expressed in 10 000 Yuan).<sup>39</sup>

### Tumor

We identified 11 studies comparing open and MIS approaches to treating spinal tumors. Nine of these studies found that MIS and open procedures did not have significantly different operative times.<sup>41-49</sup> The remaining 2 studies found that the MIS approach resulted in significantly shorter operative times.<sup>50,51</sup> Ten studies evaluated intraoperative blood loss, and all<sup>41-45,47,49-51</sup> but one<sup>48</sup> found that MIS surgical techniques resulted in significantly less blood loss. Ten studies reported results on LOS, of which 7 studies favored MIS<sup>42,44,46-50</sup> and 3 studies did not find a significant difference<sup>41,43,45</sup> between the 2 approaches. No studies were identified that compared the costs/hospitalizations charges between MIS and open approaches.

### Deformity

We identified 7 studies comparing open and MIS approaches to treating spinal deformities. In terms of operative time, 1 study favored open,<sup>52</sup> 2 studies favored MIS,<sup>53,54</sup> and the remaining 4 studies found no significant difference<sup>55-57</sup> between the 2 approaches. All 7 studies reported significantly less blood loss associated with MIS approaches.<sup>52-58</sup> Of the 6 studies that reported results on LOS, 2 studies favored MIS<sup>54,58</sup> and the remaining 4 studies did not find any significant differences<sup>52,53,55,57</sup> between the open and MIS approaches. Only 2 studies reported findings on costs and both found that MIS approaches resulted in significantly lower costs/hospitalization charges.<sup>52,54</sup>

In the first study, Uddin et al conducted a comparative study in their 71 patients (33 open, 38 MIS; ie, TLIF or lateral lumbar interbody fusion) undergoing adult deformity correction for degenerative scoliosis. Utilizing cost data from institutional billing departments, they found that MIS techniques were

**Table 1.** Average Patient Reimbursement for Open and MIS Fusion and Discectomy Approaches.

	Average	Standard deviation	P value
Posterior I-level fusion	\$40 485.62	\$60 717.25	.015
Posterior I-level MIS fusion	\$9824.83	\$22 829.19	
Posterior multilevel fusion	\$39 347.14	\$56 421.36	.023
Posterior multilevel MIS fusion	\$6848.81	\$17 095.70	
Discectomy	\$38 756.96	\$53 423.94	.01
MIS discectomy	\$8327.03	\$22 441.46	

Abbreviation: MIS, minimally invasive surgery.

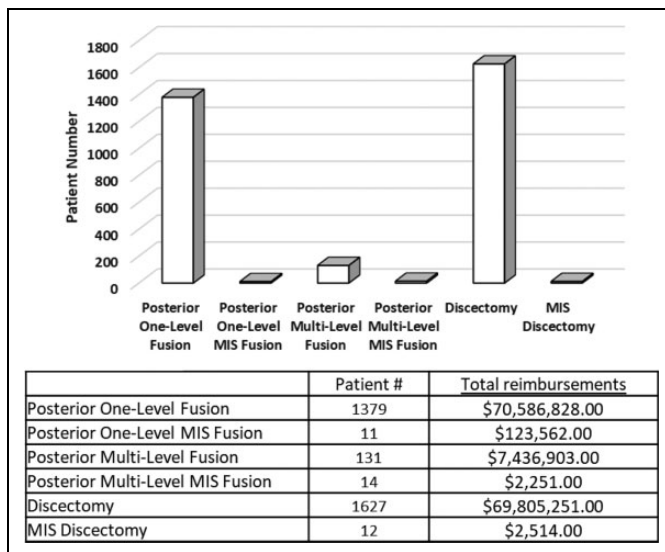
associated with significantly lower inpatient and total charges. Average inpatient charges for MIS were \$269 807 compared to \$391 889 ( $P < .01$ ) for equivalent open procedures. When adjusting for inflation, the cost savings for inpatient charges associated with MIS was maintained (\$292 329 for MIS, compared to \$433 620 for open;  $P < .01$ ). Specifically, an approximate \$50 000 savings was observed when comparing costs related to operative time between the 2 groups, favoring MIS;  $P = .01$ . Furthermore, MIS was associated with significantly lower mean charges for the use of blood products, cardiac ancillary services, imaging, laboratory tests, pharmacy, and routine nursing costs.<sup>54</sup>

In their study of 22 patients who underwent T11-pelvis fusions (10 open, 12 transposas) with 12-month follow-up, Swamy et al found that use of MIS resulted in an incremental cost savings of \$27 869 (CAD) and was associated with 0.06 more QALYs in patients when accounting for the costs associated with complications. In cases without complications, however, the minimally invasive approach was associated with an incremental cost *increase* of \$28 715. Nonetheless, utilizing a probabilistic analysis, they found that the minimally invasive approach was less costly and more effective when compared to the open technique 57% of the time. They concluded that MIS was associated with cost savings and higher quality care when compared to equivalent open surgery.<sup>52</sup>

A recent study by Park et al found that patient factors influence the decision on the type of surgical approach for the treatment of adult spine deformity.<sup>59</sup> Age, Numerical rating Scale (NRS), pelvic incidence-lumbar lordosis, T1 pelvic angle and coronal curve were significant factors contributing to the surgical choice. Increasing age was indicator of MIS approach, while higher NRS score or more severe deformity were indicators for open approach.

### Hospital Reimbursements—PearlDiver Data

Anterior MIS approaches led to reimbursements from <11 patients and thus anterior reimbursements were not included in the analysis. Across both posterior fusion or discectomy procedures, open approach was associated with higher reimbursements when compared to the respective MIS approach (Table 1). Reimbursement for open posterior I-level fusion was significantly higher than for corresponding MIS procedure



**Figure 1.** Patient number and total reimbursement for 2016.

(\$40 485.62 vs \$9824.83,  $P = .015$ ). Similar significant trends were seen for multilevel posterior fusion. Difference in the reimbursement between open and MIS discectomy approach was \$30 429.93, with open approach having significantly higher costs ( $P = .01$ ; Table 1).

In 2016, open approaches were performed more frequently than MIS approaches within the Mariner claim database (Figure 1). The most common approaches in 2016 were single-level posterior fusion and discectomy, which also were associated with the highest relative total hospital reimbursements.

### Discussion

In the last 2 decades, there has been a rapid expansion in the number of MIS surgical techniques that have become available to spine surgeons for the treatment of a myriad of spinal conditions. As surgeons have become more proficient with these techniques and technology has evolved, there is mounting evidence that MIS techniques decrease blood loss, shorten hospital lengths of stay, mitigate complications, decrease perioperative pain, and enable quicker return to daily activities when compared to equivalent open surgical techniques. Consequently, these latter benefits may translate to cost savings that may actually offset more expensive up-front costs, resulting in potential net savings in most surgical settings.<sup>5,7-11,52</sup> Additionally, significant advancements in postoperative pain management protocols have further helped drive down costs associated with surgical episodes of care by enabling many MIS spine procedures to be performed in an outpatient setting. Finally, by maximally preserving normal anatomy, MIS techniques may theoretically mitigate the risks of iatrogenic instability and adjacent segment degeneration in the long-term, yielding further potential cost savings. However, despite an emerging body of evidence to support the cost-effectiveness of MIS when compared to equivalent open techniques, this data is plagued

by a lack of uniformity in cost reporting and in the comparative methodology used for cost-effectiveness analyses.

It is generally accepted that cost-effectiveness analysis is the best assessment of value. This type of analysis involves the calculation of incremental cost-effectiveness ratios (ICER), which are reported as a cost amount per QALY gained. Classically, the benchmark \$50 000 per QALY had been set as the threshold for cost-effectiveness since the 1970s.<sup>60</sup> However, there are significant limitations to this metric. Although unclear, it is thought that this value was calculated within the context of end-stage renal disease, which may limit its translatability to other clinical or surgical settings. Furthermore, given its dated origins, quality per cost may vary secondary to monetary inflation, market forces, and an overall increase in medical spending over the years. Inconsistencies in the definition or calculation of cost are also sources of ICER variability. Consequently, in the literature, multiple ICER thresholds have been utilized throughout the years.<sup>61</sup> In spine, a benchmark of \$120 000 per QALY has even been suggested.<sup>62</sup> This substantial heterogeneity in respective data reporting ultimately underscores the fact that despite its acceptance as the standard in reporting cost-effectiveness, ICER is not without its own notable limitations. Ultimately, we found this type of cost analysis rare in the comparative studies we reviewed. Only one study reported their results within the context of ICER.<sup>52</sup>

Unfortunately, given that tubular or mini-open procedures do not have a separate procedural code from open procedures, we were unable to make these cost comparisons in our analyses of the PearlDiver dataset. We did, however, find that percutaneous and endoscopic procedures were associated with cost-savings when compared to open surgeries. While these findings are quite preliminary, with interest in spinal endoscopy at an all-time high, especially outside of the United States, it may suggest that an additional benefit to use of spinal endoscopy is potential cost savings.

With the health care landscape becoming more patient centric and cost conscious, the demand for minimally invasive spine surgery continues to rise. Current evidence appears to support the potential superiority of MIS-based procedures with regard to short-term outcomes when compared to equivalent open procedures. Furthermore, while initial start-up costs may in some instances be more expensive with use of MIS techniques, when considering the total cost of associated care, current data suggests that overall cost-savings may be incurred with use of MIS techniques. Further savings may be incurred with percutaneous and endoscopic surgery. However, data reporting on costs lacks in uniformity making it difficult to formulate any firm conclusions regarding any incremental improvements in cost-effectiveness that may be incurred when utilizing MIS techniques when compared to equivalent open techniques. Future research should focus on implementing a standardized approach to cost-effectiveness reporting valid, like-to-like comparisons in interventions are made.

## Declaration of Conflicting Interests

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