Cost-effectiveness analysis in minimally invasive spine surgery

LUTFI T. AL-KHOUIA, B.S.,1 ELI M. BARON, M.D.,1 J. PATRICK JOHNSON, M.D.,1,2 TERRENCE T. KIM, M.D.,3 AND DONIEL DRAZIN, M.D.1

Departments of 1Neurosurgery and 1Orthopaedics, Cedars-Sinai Medical Center, Los Angeles; and 2Department of Neurosurgery, UC Davis Medical Center, Sacramento, California

Object. Medical care has been evolving with the increased influence of a value-based health care system. As a result, more emphasis is being placed on ensuring cost-effectiveness and utility in the services provided to patients. This study looks at this development in respect to minimally invasive spine surgery (MISS) costs.

Methods. A literature review using PubMed, the Cost-Effectiveness Analysis (CEA) Registry, and the National Health Service Economic Evaluation Database (NHS EED) was performed. Papers were included in the study if they reported costs associated with minimally invasive spine surgery (MISS). If there was no mention of cost, CEA, cost-utility analysis (CUA), quality-adjusted life year (QALY), quality, or outcomes mentioned, then the article was excluded.

Results. Fourteen studies reporting costs associated with MISS in 12,425 patients (3675 undergoing minimally invasive procedures and 8750 undergoing open procedures) were identified through PubMed, the CEA Registry, and NHS EED. The percent cost difference between minimally invasive and open approaches ranged from 2.54% to 33.68%—all indicating cost saving with a minimally invasive surgical approach. Average length of stay (LOS) for minimally invasive surgery ranged from 0.93 days to 5.1 days compared with 1.53 days to 12 days for an open approach. All studies reporting EBL reported lower volume loss in an MISS approach (range 10–392.5 ml) than in an open approach (range 55–535.5 ml).

Conclusions. There are currently an insufficient number of studies published reporting the costs of MISS. Of the studies published, none have followed a standardized method of reporting and analyzing cost data. Preliminary findings analyzing the 14 studies showed both cost saving and better outcomes in MISS compared with an open approach. However, more Level I CEA/CUA studies including cost/QALY evaluations with specifics of the techniques utilized need to be reported in a standardized manner to make more accurate conclusions on the cost effectiveness of minimally invasive spine surgery.

(See thejns.org/doi/abs/10.3171/2014.4.FOCUS1449)

Key Words • minimally invasive surgery • spine • cost analysis • cost-utility analysis • cost-effectiveness analysis

With an increased emphasis on a value-based health care system, a push for providers to deliver cost-effective services has become the forefront of research and policy making. The goal of this trend is to provide quality health care while minimizing the cost of the intervention. With increasing innovations in the field of medicine and the number of treatment options that are offered to patients (imposed on an economically conscious system), the question we need to ask ourselves is which of these interventions will generate a maximal benefit while minimizing costs. The basis of this economic evaluation of our current treatment methods is not intended to choose the least expensive option but to determine a balance between cost-effective means of an intervention that also meets acceptable societal outcome standards.

An economic evaluation is performed to compare the costs and outcomes of 2 or more interventions. Cost-effectiveness analysis (CEA) and cost-utility analysis (CUA) are 2 types of economic evaluations that can be performed to help guide our decision-making process in determining the overall value of each intervention based on these costs and outcomes. The results of a CEA/CUA are commonly measured by a validated, standardized metric known as quality-adjusted life years (QALYs). The QALY metric is a measure of a patient’s disease burden including both the quality and quantity of life lived that best assesses the extent of benefits gained from an intervention. When combined with cost information, an incremental cost-effectiveness ratio can be calculated between
2 interventions and provide a cost per QALY value: the lower the value, the more cost-effective the new strategy. Currently, the threshold for this value is controversial, but most studies use less than $50,000–$100,000/QALY gained to deem a new strategy as cost-effective.

In 2003, spine surgery costs accumulated to more than $1 billion in Medicare spending and spiraled to more than $3.9 billion in the 2012 fiscal year (October 1, 2011 to September 30, 2012). Total spine-related health expenditures have topped $85.9 billion, with some estimates reporting $90 billion with an additional $10–$20 billion in indirect costs.\(^{14}\) One study by Martin et al. reported a 65% increase in health care expenditure for spine care between 1997 and 2005.\(^{14}\) Additionally, Davis et al. noted a 15% increase in ambulatory visits for a primary diagnosis of a spine condition between 1999 and 2008, which accounted for approximately 6% of all ambulatory visits for US adults.\(^{8}\) This rapid increase in costs and the finite amount of health care resources in the setting of a growing need for spine care demonstrate the importance of performing economic evaluation studies to determine cost-effectiveness. Rihn et al. reported a 70% increase in CEA studies of the lumbar spine between 2004 and 2009 compared with between 1999 and 2004, but that total still represented less than 1% of all articles published on the lumbar spine within the same timeframe.\(^{23}\) In particular, there has been a lack of full CEA/CUA analyses for minimally invasive spinal procedures to help compare its value to that of open techniques.

The purpose of this study was to perform a comprehensive literature review of all CEA/CUA analyses specifically on minimally invasive spine surgery (MISS). This will help us address the relationship between MISS and open surgery in terms of costs, outcomes, and utility in our value-based health care system.

**Methods**

**Overview**

A literature review was performed using PubMed, the CEA Registry, and the National Health Service Economic Evaluation Database (NHS EED) to find articles evaluating the cost of MISS. Articles were excluded if the study was conducted in a health care facility outside the US or was published in a language other than English. Each article was screened for inclusion and exclusion criteria after reading the abstracts and identifying the outcomes or end points being analyzed by the authors. If there was no mention of cost, CEA/CUA, QALY, quality, or outcomes mentioned, then the article was excluded. No preference was made regarding the type of MISS performed or the area of the spine (cervical vs thoracic vs lumbar). Only papers comparing MISS with open procedures were found to have reported costs (whether direct, indirect, or total). We defined direct and indirect costs as described by Allen and Garfin and Tosteson et al.\(^{28,29}\) In brief, direct costs pertain to the costs of surgery, hospital stay, medications, laboratory tests/imaging, and so on during a patient’s stay for surgery. Conversely, indirect costs are incurred from productivity loss as a result of the relative injury and include missed days/wages from work and missed days from homemaking. Total cost is determined to be the total of both direct and indirect costs and reflects the overall economic value of an intervention.

**Systematic Literature Review**

The literature search was performed using key words/MeSH terms to screen for papers of interest. The same set of key words was used in each database (PubMed, CEA Registry, and NHS EED): spine, spine surgery, minimally invasive spine, minimally invasive spine cost, spine QALY, and economics of minimally invasive spine. Abstracts were reviewed for the inclusion and exclusion criteria previously mentioned. Two articles were identified through NHS EED, 3 through the CEA Registry, and the other 9 through PubMed.

**Data Variables**

While reading through each paper, we focused our data collection on identifying costs (direct, indirect, and total), follow-up length, length of stay (LOS), estimated blood loss (EBL), surgery site infection (SSI), type of study, and type of MISS, if reported. The primary outcome of interest in this study is the cost of minimally invasive spine procedures. Direct, indirect, and total costs were identified and analyzed. Comparisons were made between MISS and open procedures to help determine the utility of a minimally invasive approach in regard to these outcomes. Secondary points of interest include surgical outcomes from these same approaches that are reported in the studies reviewed for cost.

**Results**

Fourteen studies reporting costs associated with MISS in 12,425 patients (3675 MISS and 8750 open) were identified through PubMed, the CEA Registry, and NHS EED. Of the 14 studies collected in this literature review for analysis, 11 (78.6%) were retrospective and 3 (21.4%) were prospective (Table 1). No studies reported performing a randomized controlled trial (RCT). All studies used in this analysis involved minimally invasive surgery of the lumbar spine and were published between 1998 and January 2014. Follow-up length among all studies ranged from 60 days to 5.05 years, with 5 of the 14 studies not having reported these data.

All but one study calculated direct costs, while only 3 studies reported indirect costs (21.4%). Parker et al. reported a $6650 indirect cost saving with an MISS approach in regard to missed work for the open group.\(^{16}\) We were not able to make cost comparisons between the studies with sufficient accuracy and statistical significance since all of the studies either reported costs differently or used different surgical procedures. However, we calculated the percent cost difference between MISS and open surgery to help establish a trend among the individual studies. The percent cost difference ranged from 2.54% to 33.68%, all indicating lower cost with an MISS approach. Two of the 14 studies had insufficient reported data to calculate a percent cost difference, but both indicated increased expenditures with an open approach.\(^{3,15}\)
**TABLE 1: Cost utility studies**

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Patients</th>
<th>No. of MISSs</th>
<th>No. of Open Ops</th>
<th>Mean Follow-Up</th>
<th>Type of Study</th>
<th>Type of Op</th>
<th>Mean MISS Cost</th>
<th>Mean Open Op Cost</th>
<th>% Cost Difference</th>
<th>Direct Costs Calculated?</th>
<th>Indirect Costs Calculated?</th>
<th>QALY Analysis Performed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cahill et al., 2013</td>
<td>81</td>
<td>48</td>
<td>33</td>
<td>NR</td>
<td>retrospective</td>
<td>microdiscectomy</td>
<td>$22,358</td>
<td>$27,811</td>
<td>19.60%</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Cheng et al., 2013</td>
<td>75</td>
<td>50</td>
<td>25</td>
<td>5.05 ± 1.4 yrs</td>
<td>retrospective</td>
<td>1-level TLIF</td>
<td>NR</td>
<td>NR</td>
<td>savings of $3885 w/ MISS</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Lucio et al., 2012</td>
<td>210</td>
<td>109</td>
<td>101</td>
<td>2 yrs</td>
<td>retrospective</td>
<td>2-level PLIF</td>
<td>$24,320.16</td>
<td>$27,055.53</td>
<td>10.11%</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Parker et al., 2012</td>
<td>30</td>
<td>15</td>
<td>15</td>
<td>2 yrs</td>
<td>prospective</td>
<td>1-level TLIF</td>
<td>$35,996</td>
<td>$44,727</td>
<td>19.50%</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Parker et al., 2013</td>
<td>54</td>
<td>27</td>
<td>27</td>
<td>2 yrs</td>
<td>retrospective</td>
<td>hemilaminectomy</td>
<td>$23,109</td>
<td>$25,420</td>
<td>9.10%</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Parker et al., 2013</td>
<td>100</td>
<td>50</td>
<td>50</td>
<td>2 yrs</td>
<td>prospective</td>
<td>1-level TLIF</td>
<td>$38,563</td>
<td>$47,858</td>
<td>19.40%</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Pelton et al., 2012</td>
<td>66</td>
<td>33</td>
<td>33</td>
<td>NR</td>
<td>retrospective</td>
<td>1-level TLIF</td>
<td>WC: $28,060; non-WC: $29,429</td>
<td>WC: $33,862; non-WC: $32,998</td>
<td>WC: 17.13%; non-WC: 10.82%</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Singh et al., 2013</td>
<td>66</td>
<td>33</td>
<td>33</td>
<td>60 days</td>
<td>prospective</td>
<td>1-level TLIF</td>
<td>$19,912</td>
<td>$23,550</td>
<td>17.15%</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Slotman &amp; Stein, 1998</td>
<td>71</td>
<td>40</td>
<td>31</td>
<td>34 mos</td>
<td>retrospective</td>
<td>LLD</td>
<td>outpatient: $4,405; inpatient: $7192</td>
<td>inpatient: $5,723</td>
<td>inpatient % difference: 20.43%</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Smith et al., 2012</td>
<td>202</td>
<td>115</td>
<td>87</td>
<td>2 yrs</td>
<td>retrospective</td>
<td>1-/2-level ALIF</td>
<td>1-level: $91,995; 2-level: $124,540</td>
<td>1-level: $102,146; 2-level: $144,183</td>
<td>1-level: 10.0%; 2-level: 13.8%</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Wang et al., 2010</td>
<td>74</td>
<td>52</td>
<td>22</td>
<td>14 mos</td>
<td>retrospective</td>
<td>1-/2-level PLIF</td>
<td>1-level: $70,159; 2-level: $87,454</td>
<td>1-level: $78,444; 2-level: $108,843</td>
<td>1-level: 10.56%; 2-level: 19.65%</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Wang et al., 2012</td>
<td>6106</td>
<td>1667</td>
<td>4439</td>
<td>NR</td>
<td>retrospective</td>
<td>1-/2-level PLIF</td>
<td>1-level: $29,187; 2-level: $33,879</td>
<td>1-level: $29,947; 2-level: $35,984</td>
<td>1-level: 2.54%; 2-level: 5.85%</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

* LLD = laparoscopic lumbar discectomy; NR = not reported; WC = workers' compensation.
Two groups of authors, Parker et al. and McGirt et al., focused their cost analysis specifically on the costs of postoperative surgical site infection (SSI) and did not report specifically on procedural costs (Table 2).15,18 Parker et al. studied the costs associated with treating SSI after open transforaminal lumbar interbody fusion (TLIF). They compared their results with what those in the literature found a similar incidence of SSI (5% vs 4% in the literature), which is noted to be higher than SSI incidence using an MISS approach (0.6%).18 Other measured outcomes, including average EBL, LOS, and postoperative infections, are listed in Table 3. All studies reporting EBL reported a lower volume loss in MISS approaches (range 10–392.5 ml) versus an open approach (range 55–535.5 ml) (Fig. 1 upper). The mean LOS for MISS ranged from 0.93 days to 5.1 days compared with 1.53 days to 12 days for an open approach (Fig. 1 lower).

A one-tailed Student t-test was performed, and a p value was determined using the cost data collected from studies utilizing MISS-TLIF surgery, since it was the type of MISS that most of these studies performed (n = 7; Fig. 2). Of the 7 studies using TLIF, 2 studies were excluded because they only reported the cost of infection.15,18 A third study was excluded because it only reported the cost difference and not the costs of the MISS and open approaches.5 Four studies were included in the analysis, which produced a t-value of 0.00796 and p value of 0.497.

Discussion

In the current analysis, we focused our assessment on 2 major points: the monetary value and outcomes of MISS. These 2 components were analyzed separately for individual value and were then applied together to ascertain the overall cost-effectiveness of minimally invasive spinal surgery. With only 3 studies having calculated indirect costs, it is hard to get a full understanding of their influence on the total costs, thereby making it challenging to perform any direct comparisons between the studies. By calculating the percent cost difference, we are able to identify trends in the costs reported and make preliminary conclusions on the value of MISS.

Each of the 14 studies showed a total cost saving using a minimally invasive approach when appreciating the percent cost difference calculated in Tables 1 and 2. In a few of these studies, the authors reported either equal or higher procedural cost with a minimally invasive approach, but this initial cost difference was offset by increased postoperative costs for the open procedure.13,20,32 These increased costs are mostly attributable to higher rates of complication, longer length of stay, more blood loss, and more postoperative services used compared with a minimally invasive approach.12,13,19,24–26,31 Additionally, studies have reported that a minimally invasive approach has been shown to be associated with faster narcotic independence, faster return to work after surgery, decreased pain, and decreased surgical time.16,19,22,27 A review article by Parker et al. found accelerated return to work and narcotic independence after minimally invasive TLIF compared with open TLIF.19 However, few other

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Patients</th>
<th>No. of Open Ops Follow-Up Type of Study</th>
<th>Type of MISS</th>
<th>Mean MISS Cost</th>
<th>Mean Open Op Cost</th>
<th>% Cost Difference</th>
<th>Direct Costs Calculated?</th>
<th>Indirect Costs Calculated?</th>
<th>QALY Analysis Performed?</th>
<th>No. ofMISSs</th>
<th>No. of Open Ops</th>
<th>Type of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>McGirt et al., 2011</td>
<td>5170</td>
<td>1436</td>
<td>3734</td>
<td>$684</td>
<td>$724</td>
<td>1-level: 5.52%</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>1-level: $756</td>
<td>2-level: $1140</td>
<td>NR</td>
</tr>
<tr>
<td>Parker et al., 2011</td>
<td>120</td>
<td>0</td>
<td>120</td>
<td>$29,110</td>
<td>UTD</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>NR</td>
<td>NR</td>
<td>UTD</td>
</tr>
<tr>
<td>Authors &amp; Year</td>
<td>No. of Patients (%)</td>
<td>Mean LOS (days)</td>
<td>Mean EBL (ml)</td>
<td>Postop Infection (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------</td>
<td>-----------------</td>
<td>---------------</td>
<td>----------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>Male</td>
<td>Female</td>
<td>MISS</td>
<td>Open Op</td>
<td>MISS</td>
<td>Open Op</td>
<td>MISS</td>
<td>Open Op</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cahill et al., 2013</td>
<td>76</td>
<td>36 (47.4)</td>
<td>40 (52.6)</td>
<td>0.93</td>
<td>1.53</td>
<td>NR</td>
<td>NR</td>
<td>2.1</td>
<td>7.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheng et al., 2013</td>
<td>75</td>
<td>41 (54.7)</td>
<td>34 (45.3)</td>
<td>4.8 ± 1.8</td>
<td>6.05 ± 1.8</td>
<td>392.5 ± 284.0</td>
<td>535.5 ± 324.0</td>
<td>NR</td>
<td>NR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lucio et al., 2012</td>
<td>210</td>
<td>93 (44.3)</td>
<td>117 (55.7)</td>
<td>1.2</td>
<td>3.2</td>
<td>NR</td>
<td>NR</td>
<td>0</td>
<td>2.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>McGirt et al., 2011</td>
<td>5170</td>
<td>2356 (45.6)</td>
<td>2814 (54.4)</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>1-level: 4.5; 2-level: 4.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parker et al., 2011</td>
<td>120</td>
<td>50 (41.7)</td>
<td>70 (58.3)</td>
<td>NR</td>
<td>12 ± 10</td>
<td>NR</td>
<td>NR</td>
<td>0</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parker et al., 2012</td>
<td>30</td>
<td>12 (40.0)</td>
<td>18 (60.0)</td>
<td>3</td>
<td>5</td>
<td>200</td>
<td>295</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parker et al., 2013</td>
<td>54</td>
<td>29 (53.7)</td>
<td>25 (46.3)</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parker et al., 2013</td>
<td>100</td>
<td>34 (34)</td>
<td>66 (66)</td>
<td>3</td>
<td>4</td>
<td>200</td>
<td>350</td>
<td>0</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelton et al., 2012</td>
<td>66</td>
<td>44 (66.7)</td>
<td>22 (33.3)</td>
<td>WC: 2 ± 0.786; non-WC: 2 ± 0.64</td>
<td>WC: 3 ± 0.94; non-WC: 3 ± 1.26</td>
<td>WC: 127 ± 103.35; non-WC: 124 ± 61.5</td>
<td>WC: 254 ± 48.66; non-WC: 288 ± 121.17</td>
<td>NR</td>
<td>NR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Singh et al., 2013</td>
<td>66</td>
<td>44 (66.7)</td>
<td>22 (33.3)</td>
<td>2.3 ± 1.2</td>
<td>2.9 ± 1.1</td>
<td>124.4 ± 92.0</td>
<td>380.3 ± 191.2</td>
<td>NR</td>
<td>NR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slotman &amp; Stein, 1998</td>
<td>71</td>
<td>33 (46.5)</td>
<td>38 (53.5)</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>55</td>
<td>NR</td>
<td>NR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smith et al., 2012</td>
<td>202</td>
<td>98 (48.5)</td>
<td>104 (51.5)</td>
<td>1-level: 1.51; 2-level: 1.78</td>
<td>1-level: 3; 2-level: 4</td>
<td>1-level: 79.1; 2-level: 95.6</td>
<td>1-level: 241.7; 2-level: 353.8</td>
<td>1-level: 1.6; 2-level: 0</td>
<td>1-level: 6.3; 2-level: 5.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wang et al., 2010</td>
<td>74</td>
<td>NR</td>
<td>NR</td>
<td>1-level: 3.9 ± 1.06; 2-level: 5.1 ± 4.05</td>
<td>1-level: 4.8 ± 1.42; 2-level: 7.1 ± 3.39</td>
<td>1-level: 145 ± 73; 2-level: 187 ± 66</td>
<td>1-level: 400 ± 116; 2-level: 493 ± 169</td>
<td>0</td>
<td>1-level: 0; 2-level: 14.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wang et al., 2012</td>
<td>6106</td>
<td>2745 (45.0)</td>
<td>3361 (55.0)</td>
<td>1-level: 3.35; 2-level: 3.4</td>
<td>1-level: 3.6; 2-level: 4.03</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
studies have reported on the relation of type of spine surgery and narcotic use, which can be another useful statistic in determining the overall effectiveness in relieving pain in the short and long term.

Parker et al. showed that both direct and indirect costs were higher in an open TLIF ($2081 difference in direct costs and $6650 difference in indirect costs—an average cost saving of $8731, p = 0.18).16 It is important to point out the larger cost difference associated with indirect costs in this study, which is greater than 3 times more than the savings in direct costs. Another study by Parker et al. evaluating MISS versus open multilevel hemilaminectomy showed similar results with a cost saving of $628 in direct costs and $1683 in indirect costs (> 2.5 times more savings in indirect costs).17 This further exemplifies the impact of indirect costs in determining whether MISS is truly more cost-effective than open spine surgery and the need for more studies reporting indirect costs. Allen and Garfin discussed the potential of MISS to increase societal productivity as patients have a quicker recovery, shorter LOS, and faster return to work, which, theoretically, will all result in lower indirect costs for MISS patients and increased societal productivity.18 Udeh et al. performed a 2-year cost analysis to compare 3 different treatment options for lumbar spinal stenosis (epidural steroid injection, minimally invasive lumbar decompression, and laminectomy) and found greater cost-effectiveness with the MISS approach ($43,760/QALY vs $37,758/QALY for epidural steroid injection vs $125,985/QALY for laminectomy).29 Udeh and colleagues’ study reported similar outcomes to what we reviewed in this study. However, we were unable to include it in the analysis, as there was no specific mention of the number of patients receiving each treatment modality or their outcomes. Notably, Udeh and colleagues’ study did find that a minimally invasive approach was more cost-effective than a nonsurgical treatment option, as well as an open laminectomy.29

Another component that needs to be addressed in this CEA is the impact of SSI on total costs. A higher infection rate will likely result in greater medical spending to treat the infection, longer hospitalization after surgery, longer time to recover, and longer duration until the patient is able to return to work. Parker et al. performed a literature review to identify the rates of postoperative infection for both MISS and open TLIF and identified an average infection incidence of 0.6% in MISS compared with 4.0% in the open TLIF series.18 The rate of SSI after open TLIF was similar to their cohort of 120 patients who showed a 5% incidence after open TLIF, amounting to $29,110 in costs for post-TLIF SSI care. Similarly, McGirt et al. found a higher cost of SSI treatment in open PLIF/TLIF procedures, showing a 5.52% cost difference for 1-level fusion and a 33.68% difference for a 2-level fusion.15 Both of these studies report a higher incidence of SSI with an open approach along with more costly implications of further treatment and care of the complication.

Several studies have been performed to determine the effectiveness of an MISS approach without reference to cost. These studies are important in illustrating a wider view on the advantages and disadvantages of minimally invasive spine surgery. These findings can then be combined with the results of a cost analysis to achieve a multidisciplinary understanding of MISS. Karikari and Isaacs came to a similar conclusion as the current study in that there is a potential superiority of MISS over open surgeries, but more long-term data need to be published to assess outcomes.10 The efficacy of a minimally invasive approach in relieving chronic pain has been reviewed and has been shown to be equally as beneficial as an open approach. A meta-analysis by Dasenbrock et al. examined the differences in leg pain relief after patients underwent either a minimally invasive or open approach and found equivalent improvement at the 1- to 2-year follow-up points.7 Minimally invasive spine surgery and open procedures were associated with postoperative improvement to a visual analog scale score of 1.6 from preoperative
Cost-effectiveness analysis in MISS

values of 6.9 and 7.2, respectively. Other studies have also found a minimally invasive approach to be at least equally effective or more effective than an open approach with regard to overall pain reduction.9,29,30

Study Limitations

The costs summarized in Table 1 have not been adjusted for inflation. However, using the calculated percent difference in each individual study helps standardize the values and allows for more accurate comparison of the data. Most of the studies used different definitions of costs (some chose to report the total costs while others only reported the direct costs), which makes it difficult to make direct comparisons between studies. It is important to note that 3 (21.4%) of the 14 studies did not provide specific details on the surgical techniques used. There can be a lot of variability in surgical technique; therefore, reporting more details regarding the approach can provide greater insight on the differences in costs for similar procedures.

Including different types of minimally invasive spine procedures allowed for greater variation in costs, but this helped establish a similar trend of cost-effectiveness across different types of MISS. Utilizing data directly from the hospital via the Nationwide Inpatient Sample can provide us with a more standardized method of reporting costs and is possibly a source for future research and evaluation. Additionally, the Thomson Reuters MarketScan provides medical intervention outcomes evaluation for approximately 158 million unique patients from 1995 onward, which can be used to further analyze the utility of MISS.

Future Outlook

While the number of CEA/CUA studies on MISS is scant, there is a growing importance in reporting the costs associated with MISS. This information can serve as a useful tool in helping providers determine which intervention will provide sufficient benefit to the patient at a lower cost. Looking forward, we need more standardized CEA/CUA studies reporting on MISS to make more accurate comparisons on the preliminary conclusions drawn in this current study as well as others publishing similar findings. Allen and Garfin and Kepler et al. provided good outlines on the different components needed in a CEA/CUA study and address important questions that need to be addressed in each study.1,11 This standardization would ideally involve calculating QALYs, which can be used to calculate a cost-effectiveness ratio to directly compare to open spine surgery: cost-effectiveness ratio = (COSTmiss - COSTopen)/(QALYmiss - QALYopen).

Furthermore, Parker and McGirt introduced the concept of minimal clinical important difference and minimal cost-effective difference in relation to spine surgery. These tools can be useful in determining the minimal level of improvement thought to be meaningful to patients.21 A CEA should be performed as outlined by the US Panel on Cost-Effectiveness in Health and Medicine (1996) with 4 components: “the use of the societal perspective, appropriate incremental comparisons between treatments, appropriate discounting of both the cost and health effect of the treatment, and the use of a community preference-based utility measure.”22,11,33 Additionally, studies utilizing the Nationwide Inpatient Sample and Thomson Reuter MarketScan databases, which have a large selection of patients with standardized reported values, can provide some useful data on this subject.

The p value calculated does not show any significant findings in regard to the effectiveness of MISS TLIF (p = 0.497). This further supports that there are insufficient CEA/CUA data reported to accurately make a conclusion on the efficacy of MISS. Furthermore, more RCTs are needed to evaluate the true efficacy of MISS compared with an open procedure. From the studies we reviewed, there was no mention of randomization or reporting of how the patients were placed into the MISS or open group. Randomized controlled trials will help provide more Level I evidence and further allow us to determine the effectiveness of MISS and reflect on how it can be used in the real world. Randomized controlled CEA/CUA studies reporting costs from a societal perspective (which includes both direct and indirect costs) would help further explore this question. Publishing indirect cost data using a minimal 2-year follow-up period is preferred to better determine all indirect costs acquired after surgery.

In planning for future CEA studies, having a standardized method in structuring the study design and data collection can help provide higher-quality data for analysis. The Center for Disease Control and Prevention and the US Department of Health and Human Services have put together tutorials on economic evaluation of public health, which includes CEA.4 A basic structural starting point for a high-quality CEA has been created by applying the outline provided by the Center for Disease Control to our interest in MISS (Table 4). We can then deem the results of these independent studies as “combinable” and be able to perform a statistically significant meta-analysis looking at the results of these studies with greater certainty. The end goal of this process is achieving a conclusion that can impact clinical practice.

A meta-analysis requires pooling of data from different studies to establish a greater power. This greater power is useful in determining the statistical significance of a reported outcome that otherwise could not have been
established in an individual study. This is where uniformity across the studies included in a meta-analysis becomes important. Without this uniformity, the integration of data from separate studies can become a haphazard process that may possibly lead to false conclusions. With this in mind, we need to establish a way to properly perform and review meta-analyses. Klimo et al. discussed the methodology and utilization of the Primary Reporting Items for Systematic reviews and Meta-Analyses (PRISMA), A Measurement Tool to Assess Systematic Reviews (AMSTAR), and Meta-Analysis Of Observational Studies in Epidemiology (MOOSE) to identify high-quality reviews and encourage the development of high-quality reviews in future studies. These tools allow for more objective evaluation of meta-analyses and can help authors in identifying the points necessary to make a high-quality study. Additionally, Consolidated Standards of Reporting Trials (CONSORT) has been used to assess RCTs and provide higher standards of reporting. Although the focus of this study is not on the structure of meta-analyses and RCTs, we hope that this introduction can help facilitate further attention and discussion on the topic as properly performed CEAs and concurrent meta-analyses go hand-in-hand in further exploring the topic of MISS and open spine surgery.

**Conclusions**

There is currently an insufficient amount of studies published reporting the costs of MISS. Of the studies published, none have followed a standardized method of reporting and analyzing cost data. Preliminary findings analyzing the 14 studies showed both a cost savings and better outcomes in MISS compared with an open approach. However, further investigation needs to be performed, and more concrete Level I data need to be published to have any definitive conclusions on the impact of MISS on our value-based health system.

**Disclosure**

Dr. Kim is a consultant for Synthes DePuy. The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Drazin. Acquisition of data: Al-Khouja. Analysis and interpretation of data: Drazin, Al-Khouja, Kim. Drafting the article: Al-Khouja. Critically revising the article: Drazin, Baron, Johnson. Approved the final version of the manuscript on behalf of all authors: Drazin.

**References**

Cost-effectiveness analysis in MISS

listhesis: comparative effectiveness and cost-utility analysis. World Neurosurg [epub ahead of print], 2013


