3 Economics of Minimally Invasive Spine Surgery

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Learning Objectives

- Gain an understanding of the importance of and role for economic studies in minimally invasive spine surgery from the clinician's perspective.
- Describe the different types of health economic evaluations and their respective advantages and drawbacks.
- Describe the difference between direct and indirect costs.
- Provide a summary of the literature as it relates to the economics of minimally invasive spine surgery
- Identify the current knowledge gaps and directions for future investigation.

3.1 Introduction

In most countries, the cost of healthcare has progressively increased at a rate greater than the respective national economic growth [1]. Consequently, healthcare delivery in its present state is unsustainable and, in many countries, has already resulted in increased taxation as well as decreased government funding of other vital societal services. From a macroeconomic perspective, the economic impact of healthcare interventions is critically important to all stakeholders. As stakeholders in healthcare management and delivery attempt to mitigate increasing expenditures, greater demands are made upon all therapies to describe their proven indications, report adverse events, and delineate their objective and subjective outcomes [2].

With increasing costs, it also becomes necessary for health providers and payers to assess the value (defined as the relative worth, utility, or importance) of an intervention compared to alternative interventions. These needs have been highlighted by the Institute of Medicine (IOM) as comparative effectiveness research (CER). As per the IOM, "Comparative effectiveness research is the generation and synthesis of evidence that compares the benefits and harms of alternative methods to prevent, diagnose, treat, and monitor a clinical condition or to improve the delivery of care. The purpose of CER is to assist consumers, clinicians, purchasers, and policy makers to make informed decisions that will improve health care at both the individual and population levels." [3–5] Physicians have traditionally understood and taken the perspective of safety and clinical efficacy of an intervention. However, physicians are often less familiar with the perspective and language of purchasers and policy makers, which also includes the health economic aspect of not only the intervention of interest to a specific health provider but also its impact and relevance to other relevant interventions and healthcare delivery at a macro level.

3.2 Health Economic Evaluations (HEEs)

3.2.1 The Importance of Health Economic Evaluations

From the perspective of musculoskeletal surgery, the increasing demands for surgical services will only continue to increase [6–13]. It is estimated that by the year 2030, over half of the adults in the US population will be aged over 65 years. The economic effects of degenerative disorders such as arthritis of the spine (i.e., spinal stenosis), hip, and knee within this aging population will have profound implications on the future affordability and availability of quality spine care [6–13]. Within spine surgery, the SPORT studies [14–17] have documented the sustainable efficacy and cost-effectiveness of interventions using traditional open surgical

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techniques for lumbar disk herniation, spinal stenosis, and degenerative spondylolisthesis compared to nonsurgical care at 4 years of follow-up. However, CER within the spine surgery literature from an economic perspective was until more recently generally lacking. In recent years, an increasing interest in this type of research including economic analyses has emerged. This is likely due to increasing pressure on the part of healthcare providers to justify health expenditures to payers and demonstrate that the treatments they provide are of value. Nevertheless, although the need for economic data in the current healthcare climate is increasingly important, there is a general paucity of cost-effectiveness analyses (CEA) across all surgical and nonsurgical interventions [18]. In addition, societal perceptions regarding spine surgery and its benefits, risk, and associated costs may also have an impact on the perceived value of spinal intervention, regardless of whether it demonstrated cost-effectiveness. Unfortunately, the substantial variability in results along with differences in clinical indications and techniques used further confounds existing external opinions regarding spine surgery and surgical techniques [8]. The prevailing perspectives from non-spine surgeons (i.e., payers and nonsurgical spine specialist) seem to be that much of what is done in spine surgery is for the management of low back pain and is ineffective. Our day-to-day outcomes for common diagnoses such as radiculopathy or claudication would say otherwise, but we need to continue to prove it.

With these aforementioned challenges in mind, it is important to quantify the value of surgical intervention for degenerative conditions, and these interventions must be appraised from the perspectives of the patient, direct payer, and society. As diminishing healthcare resources must be stretched further and further, resource allocation for competing pathologies including cancer and chronic conditions such as cardiovascular disorders, diabetes, and arthritis currently demands the largest portion of available funds. In a publication by Martin et al. that looked at expenditures and health status among US adults with back and neck problems, the authors noted significantly escalating cost (the vast majority of which is nonoperative) with no appreciable improvement in health status compared to non-back/neck individuals [19]. The estimated annual US expenditures for back and neck disorders ($86 billion) in 2005 have reached levels comparable to diabetes ($98 billion), cancer ($89 billion), and arthritis ($80 billion) in a similar period. These are all second to heart and stroke expenditures which are estimated at $260 billion. A discussion of societal and payer prioritization regarding relative healthcare resource allocation is clearly a complex issue which is not within the scope of this chapter but is worthy of mention to enable the reader to keep the broader perspective of payers and policy makers in mind as they increase their personal understanding of CER.

3.2.2 The Language of Health Economic Analysis

A detailed description of HEE is not within the scope of this text and thus only fundamental concepts relevant to the surgeon, from the perspective of the clinician/surgeon will be provided [20]. A common misconception from physicians and surgeons is that all HEEs are the same and only consider the bottom line, cost. There are, in fact, several types of HEE that are not interchangeable and require a more profound understanding when a clinician is considering the merit of an HEE. Some HEEs only consider cost and assume that the clinical efficacy is equal between the interventions of interest, whereas others consider both the relative cost and efficacy of the intervention. Additionally, it is important to understand the perspective of the costing data sources and whether it only considers some or all healthcare costs attributable to a specific intervention and whether societal cost, such as productivity, has been included in the analysis [20, 21]. Another important aspect of an HEE is the time horizon in which the analysis has been considered, for some studies may consider the perioperative period only whereas others evaluate costs over the lifetime of the patient. Given the potential differences in study time horizon being evaluated, one must also consider whether the assumptions and variability associated with critical analytic parameters are accurate and accounted for in the study. For HEEs where the outcome measure and cost are estimated for the lifetime of the patient, future costs and utilities are typically discounted to adjust for society's relative value placed on immediate costs and benefits compared to those in the future, a concept known as time preference [21]. Commonly, resources in the present are preferred over future resources since benefit can be derived from present resources in the interim. Most importantly when comparing interventions within the same analysis or across different analyses, it is necessary to ensure that compatible clinical, costing, analytic model assumptions, and overall economic analysis and perspective were employed between groups. Variations in these parameters can grossly impact the outcome and subsequent interpretation of an HEE. Consequently, an important

Key Points

- In the setting of limited healthcare resources, economic evaluation of therapeutic interventions is needed to demonstrate that the financial cost of the intervention is justified by the amount of value that the intervention creates for the patient.
- In healthcare, policy makers must make careful decisions about how finances are allocated such that the amount of created value is optimized while minimizing cost. This is accomplished through HEEs.

part of an HEE is the inclusion sensitivity analysis within the methodology. This enables relevant and realistic variation of important clinical and economic parameters to assess the robustness of the HEE findings and allows the reader to interpret the results based on alternate parameters that may be more consistent with their local healthcare system [21].

As HEEs can be carried out in many ways and customized to specific objectives, the outcome will be potentially interpreted differently based on the perspective taken by different stakeholders. For example, from the perspective of a private payer, the primary goal might be to obtain the greatest return on their investment. From a physician's perspective, patient outcomes and clinical outcomes such as procedural time or adverse events, regardless of the economic aspect, might be the major issues of consideration. From the patient's or a societal viewpoint, personal factors such as quality of life post-surgery, recovery time, and ongoing costs along with activity factors such as days of work missed and productivity losses may be most relevant.

3.2.3 Definitions of HEEs

The most basic type of economic analysis is cost analysis (CA) which compares the cost of healthcare interventions and does not consider differences in health outcomes [20]. This type of analysis is obviously very "payer" focused; it evaluates interventions based on their costs only, and from a clinical perspective this type of analysis is not useful for CER, but represents the most common analysis in the surgical literature. Another type of economic analysis is cost-minimization analysis (CMA) which determines and evaluates the least expensive interventions among the interventions that have demonstrated the same outcomes. This type of analysis may be tedious to complete because one must first demonstrate that the resulting outcomes between interventions are, in fact, the same, which can prove to be a challenging task on its own. A CMA can be effective at any level where reducing expenditure is a priority and therapeutic equipoise from high-quality evidence has been established between two interventions for the same clinical scenario. A cost-benefit analysis (CBA) refers to an HEE where both the cost of the interventions and their outcome are assessed in terms of dollars. It is reflected as the ratio of the difference in outcome (e.g., cost difference of length of stay between two interventions) over the difference in cost. A CBA ratio greater than 1 suggests a cost-benefit of the intervention under evaluation. From a CER perspective, a cost-effectiveness analysis (CEA) which simultaneously considers both the comparative clinical effectiveness and cost of intervention is the HEE method of choice [20]. Thus, being cost-effective does not necessarily mean an intervention is less expensive up front.

3.2.4 Cost-Effectiveness (CEA) and Utility (CUA) Analyses

The primary premise of a CEA is the measurement of the incremental cost and patient benefit that result from choosing one intervention option over another [22, 23]. The purpose is to assist decision-makers in determining how to allocate resources across a defined number of competing needs to optimize health outcomes while adhering to budgetary constraints [23]. CEA is distinct from the aforementioned economic analyses such as a CA or CBA, as it simultaneously considers clinical effectiveness and cost. Within healthcare, CEA is utilized in scenarios where assigning a monetary value to a health state may be inappropriate. A CEA is typically calculated using an incremental cost-effectiveness ratio (ICER), which equals the cost of a new strategy less the cost of current practice, divided by the clinical change in outcome of the new strategy, minus the current practice [24].

$$\text{ICER} = \frac{\text{Cost}_{\text{new strategy}} - \text{Cost}_{\text{current practice}}}{\text{Effect}_{\text{new strategy}} - \text{Effect}_{\text{current practice}}}$$

The ICER analysis typically assumes that the new strategy is likely to cost more but has a clinically greater effect and is hence used to determine the cost per incremental difference in outcome.

Key Points

All of the following are different types of HEEs:

- Cost analysis (CA)—Compares the costs of two or more interventions without taking outcomes into consideration.
- Cost-minimization analysis (CMA)—Compares the costs of two or more interventions, whose outcomes have been demonstrated to be equivalent.
- Cost-benefit analysis (CBA)—HEE where two interventions are compared and both the cost and the outcomes of the intervention are measured in monetary units.
- Cost-effectiveness analysis (CEA) and cost-utility analysis (CUA)—HEEs which compare interventions while considering both financial cost and clinical effectiveness.

3.2.5 Components of A CEA

As stated previously, economic analysis can be a complex and difficult task, especially when cause-and-effect relationships are not very easily measured. Another aspect which increases difficulty is the sheer volume of variables that can contribute to the overall cost of a health intervention. Thus, collecting detailed costing data is very time-consuming and costly and represents a significant barrier in performing CEAs. Often, it can be beneficial to break down the analysis into two smaller analyses: factors that directly contribute to cost and factors which have an indirect effect on cost.

3.2.5.1 Direct Costs

Direct costs are tangible costs such as the cost of medical tests, implants, operating room time, rehabilitation, or out-of-pocket cost for payment of healthcare services that an individual may no longer be able to perform as a direct result of a disease state.

Proponents [25–31] of minimally invasive procedures frequently cite that the advantage of MIS versus open surgery is its ability to lower postoperative morbidity. In a review by Allen and Garfin, the authors outlined the factors in open procedures that may increase cost relative to MIS [32]. Factors such as increased blood loss and subsequently transfusion rates, extended OR time, and the use of open posterior approach to the spine can increase the likelihood of adverse events, such as infection, and procedure-related morbidity, such as pain [32–34]. For example, the costs surrounding a unit of blood transfused are estimated to be just under $1200, and this measure is often associated with increased LOS and resource utilization [32]. Kalanithi et al. reported that each in-hospital complication for patients undergoing surgery for acquired spondylolisthesis was associated with an increased cost of approximately 10,000 USD, with the total cost rising to over three times the cost of the index procedure if any readmission and revision surgeries were performed [33]. Khan et al. reported that a single complication may increase hospital costs for a patient in general surgery by up to 79% [35]. Broken down further, the median costs per complication resulted in costs of 4278 USD (range, 2511–25,168 USD) and as a result increased LOS by 11–297% [35]. When complications occur, significant increases in LOS, mean total charges, and in-hospital mortality are observed [33]. Consequently, taking steps to decrease the probability of adverse events and reduce LOS by using MIS techniques, as well as other available interventions, may help lower these associated costs substantially [36].

3.2.5.2 Indirect Costs

Indirect costs are more variable and depend on what is considered to be indirectly associated with a given disease state or intervention. Consequently, the determination of indirect cost is typically much more difficult. In their simplest form, indirect cost can be those associated with direct medical cost (e.g., the estimated institutional overhead to provide a service). More commonly, indirect costs refer to societal cost such as lost productivity. However, it is also important to consider that many indirect costs from a societal perspective may also be very closely related to direct costs, further increasing complexity. For example, postoperative complications such as infections following surgery may result in longer hospital stays, greater recovery time, and additional medication costs contributing to an overall decline in health. These direct costs also influence societal indirect costs as the individual may be out of the work force for a longer time, thereby decreasing their productivity. Thus, isolating and analyzing costs independently of each other can be challenging, and results must be interpreted within a defined context and in relation to other factors as opposed to individually.

Low back pain (LBP) is a good example of indirect costs from a macroeconomic perspective. The societal costs of LBP can be substantial. LBP has become the second most common reason for patients to visit primary care providers [37]. A systematic review of studies published in 2005, evaluating the cost of low back pain noted that costs resulting from lost productivity and early retirement were the largest component of total costs, representing a median of 85% of overall costs [38]. Consequently, indirect cost, particularly from a societal perspective, is an important measure of postoperative ongoing cost beyond discharge from hospital and provides a more comprehensive allocation of the costs associated with any intervention. In a 2004 study, Fritzell et al. reported that treating an individual with open lumbar fusion surgery was less expensive (and thus more beneficial) than to have the person not contribute to societal productivity while receiving conservative care treatment [39, 40]. It follows that those indirect benefits would decrease if the surgical intervention resulted in less morbidity, faster recovery, and resumption of functional activity (e.g., work); in other words, the promise of MIS should result in reduced cost.

3.2.6 Effectiveness

Effectiveness can be measured in a variety of ways depending on the most relevant outcome of the interventions assessed. For example, if mortality rate was the best outcome measure for a new therapy, the cost-effectiveness could be represented as the incremental cost per additional life saved or cost per adverse event avoided if the outcome of interest is morbidity. For elective surgical procedures, the most common form of a CEA is a cost-utility analysis (CUA), which measures effectiveness using a generic health utility score that allows the comparison of different health states by measuring them all in terms of a single unit—the quality-adjusted life year (QALY). A QALY is a measure of the burden of a disease on life and encompasses both the quality and quantity of life lived [18, 21]. Thus, for HEEs, it represents both the effect size and durability of a given intervention.

A QALY is an index number that is calculated by multiplying the utility score associated with that treatment by the duration of treatment effect. The utility score represents the health-related quality-of-life value in a range from 0 to 1, with 0 representing death and 1 representing the best or perfect health state. The utility score used to calculate the QALY of an intervention has been derived from several existing generic health-related measures, such as the EQ-5D, Health Utilities Index, Quality of Well-Being Scale, and SF-36 (expressed as SF-6D) [41–49]. Consequently, the QALY is an outcome measure that enables decision-makers to compare the effectiveness of interventions across many different areas of medicine and different disease states. For this purpose, decision-makers utilize CEAs (and specifically CUAs) to identify the costs associated in achieving a single QALY (i.e., the relative value of a given intervention). It is important to note that currently available health utility scores are not interchangeable as they often generate different values from within the same population, and thus the cost/QALY values may differ depending on which utility score was utilized [41, 48, 49].

Equally important to the QALY effect size of an intervention on the health utility index of an individual or population is the ability of an intervention to maintain that improved health state, or the durability of the treatment effect [14, 18, 21]. Tosteson et al. have demonstrated this concept in the spine literature [14]. In their landmark report of the 4-year cost-effectiveness of surgery versus nonoperative treatment from the SPORT studies, the authors demonstrated sustainable superior results (QALYs gained) from surgical compared to nonsurgical treatment. This corresponded to an improvement in the dollars spent/QALY gained ratio (ICUR) at 4 years compared to 2 years for all three subpopulations studied. For spinal stenosis, the 2- and 4-year ICUR for surgery compared to nonoperative treatment was $77,600 and 59,400. For the treatment of intervertebral disk herniation, the ICUR decreased from $34,355 at 2 years to $20,600 at 4 years. The greatest improvement was seen for the degenerative spondylolisthesis cohort, where the ICUR went down to $64,300 at 4 years compared to $115, 600 at 2 years. In more traditional economic models, where the QALY is estimated over the lifetime of the patient based on reference case data, the ICUR will typically reduce below $10,000/QALY for musculoskeletal interventions such as hip and knee replacement or 1–2-level spinal stenosis surgery [50]. For MISS lumbar fusion, both Rouben et al. and Harris et al. have demonstrated good durability beyond the 2-year mark for MIS-TLIFs [51, 52].

Finally, when faced with a cost per QALY evaluation, recommendations exist regarding the threshold for which an intervention is considered cost-effective. Generally, an ICUR greater than $100,000 per QALY is considered too costly for the utility gained [53, 54]. This number can vary from country to country and typically ranges 50–100 K USD/QALY [21]. Furthermore, the number may vary depending on the clinical context that is being considered based on the local societal value of the given intervention (e.g., life-extending cancer surgery vs. improvement on quality of life).

Key Points

- Direct healthcare costs: Tangible costs incurred by the payer, related to healthcare resource utilization in the care of a patient. These may include the costs of diagnostic tests, the operating room, costs associated with hospitalization, and the costs associated with rehabilitation.
- Indirect healthcare costs: These are most common costs from the societal perspective, related to patient time away from the workforce and caregiver burden (i.e., loss of productivity). In addition, indirect cost may also include infrastructure and operational cost associated with direct cost items.

3.3 Clinician's Approach to HEE for MIS of the Spine

Table 3.1 demonstrates the possible relationships between cost and effectiveness and can be utilized to better discern when a CEA might be worthwhile [20]. Simply put, if a new intervention provides better outcomes and reduced cost, it has greater value than the current treatment and should be adopted. Conversely, if a new procedure is less effective and cost more, it should not be supported in its current form. All other scenarios typically will require a formal CEA to determine the relative value of an intervention compared to its alternatives [20]. From this fundamental approach, the first step would be the need to answer the question of if minimally invasive spine surgery (MISS) is clinically more or less effective when compared to open surgery.

In the last several years, an increasing number of observational studies and randomized trials comparing open versus MIS lumbar fusion techniques for degenerative conditions have been published. Across the literature, several different outcome measures have been considered to make this comparison. Details of outcomes for specific techniques are avail-

Table 3.1 Principle approach to determining the need for a formal cost-effectiveness analysis (CEA)

Effectiveness of new strategy	Costs of new strategy	
	Costs more	Costs less
More effective	CEA relevant	*New strategy is dominant—adopt*
Less effective	*New strategy is ineffective—abandon*	CEA relevant

able in chapters specific to certain MIS techniques. Recently, Goldstein et al. have published a systematic review of randomized and nonrandomized studies comparing the health economics of MIS to open techniques for posterior lumbar interbody fusion [55]. This systematic review found 45 studies, with a total of 9396 subjects that met inclusion criteria, studies comparing MIS to open trans-foraminal and posterior lumbar interbody fusion, with a minimum of 10 patients in each arm, with at least one of the following types of outcome measures: clinical, perioperative, radiographic, adverse event or economic outcome. This included 3 prospective randomized controlled trials, 17 prospective cohort studies, and 25 retrospective cohort studies. Using the GRADE system, the quality of evidence was low (19 studies) to very low (26). The perioperative outcomes included operating room (OR) time, estimated blood loss (EBL), and length of hospital stay (LOS). While there was variability in the outcomes of OR time when comparing MIS to open interbody fusion in the various studies, with some studies demonstrating longer operative times in MIS while others demonstrated reduced operative times, the MIS cohorts performed better than the open cohorts with regard to both EBL and LOS. The only radiographic outcome considered in the included studies was the rate of nonunion, of which no statistically significant difference was noted in any of the 23 studies reporting on this outcome. Complication rates were included in 35 of the included studies, and nine studies found there to be a higher complication rate in open surgery compared to MIS, while the remainder of the studies did not note a difference. Thirty-two studies included some form of patient-reported outcomes, including the VAS, ODI, SF-36, SF-12, and EQ-5D. With respect to VAS, no significant difference was reported between the MIS and open cohorts in the majority of studies. Moreover, no significant differences were noted between the MIS and open cohorts with respect to ODI, SF-36, SF-12, and EQ-5D. With respect to economic outcomes, 9 of the 45 studies included HEEs. All nine of these studies found reduced cost/charges in the MIS cohorts when compared to open surgery [55].

In addition to the aforementioned systematic review, Phan et al. performed a systematic review and economic evaluation of studies comparing the cost-utility and perioperative costs of minimally invasive (MI) versus open TLIF [56]. They searched six electronic databases for comparative studies comparing MIS versus open TLIF and reporting direct hospital costs. Studies were excluded if they contained fewer than ten patients per group or did not have a comparator group. The primary outcome of interest was direct hospital costs of MIS and open TLIF. All costs were reported in USD. Baseline data collected for all patients included age, sex, and preoperative VAS and ODI scores. Perioperative outcomes of interest included OR duration, EBL, total complication rates, and hospitalization. Two independent reviewers performed risk of bias assessment according to the Dutch Cochrane Working Group MOOSE recommendations for systematic reviews and observational studies. Clinical outcomes were assessed using standard meta-analysis techniques for calculating relative risk (RR) for binomial variables and weighted mean difference (WMD) for continuous variables. Both fixed effects and random effects models were used to calculate RR and WMD. Tests for heterogeneity were carried out. Publication bias was assessed using the funnel plot method. After completing the literature search, six articles had met inclusion criteria, three were prospective observational studies, while three were retrospective observational studies. In their results, the authors noted that direct hospital costs for MI-TLIF ranged from $10,770 to $24,201, while those for open-TLIF ranged from $12,011 to $37,681. For each study, the direct hospital cost of MI-TLIF was less than that of open-TLIF, and in the meta-analysis this finding was statistically significant (WMD, −$2820, 95% CI −4020, −1630; $I^2 = 61\%$, $p < 0.0001$). Perioperative outcomes across all studies were analyzed as well to identify any factors driving the differences in hospital costs. Significant differences were observed in EBL (WMD, −246.4 mL, 95% CI −406.23, −86.58; $I^2 = 98\%$, $p = 0.003$) and length of hospitalization (WMD, 0.99, 95% CI −1.81, −0.17; $I^2 = 96\%$, $p = 0.02$). MI-TLIF was noted to have nearly a two-fold reduction in complication rates compared to the open-TLIF patients, which trended toward significance in the analysis (RR, 0.53, 95% CI 0.26, 1.06; $I^2 = 0\%$, $p = 0.007$). Operative time between the groups did not demonstrate statistical significance (WMD, −67.05 minutes, 95% CI −169.44, 35.35; $I^2 = 100\%$, $p = 0.20$) and significant heterogeneity was noted between studies. The authors concluded that there is a trend toward significantly reduced direct hospital costs associated with MI-TLIF compared to open-TLIF, and this difference is largely driven by reduced hospital LOS, decreased blood loss, and decreased complication rates [56].

In previous literature reviews of trans-foraminal and posterior lumbar interbody fusion (TLIF and PLIF) as well as extreme and direct lateral interbody fusion (XLIF/DLIF) techniques, Karikari et al. and Youssef et al. have demonstrated perioperative outcomes favoring MIS techniques compared to open cohorts or historical controls [57, 58]. Karikari et al. specifically demonstrated that in all studies reviewed ($n = 7$) the MIS subgroup performed significantly better than the open group in perioperative measures (e.g., EBL, LOS, and OR time) [57]. In a meta-analysis performed by Wu et al. (2010), the authors assessed the fusion rate of MIS versus open TLIFs [59]. This analysis included 16 studies of open TLIF (n = 716 patients) and 8 MIS studies (n = 312 patients), they reported no difference in the fusion rate between open (90.9%, 95% CI; 86.4–94.0%) and MIS TLIF (94.8%, 95% CI; 85.4–98.3%). They also noted that the reported complication rates trended toward a lower rate in MIS (7.5%, 95% CI; 3.0–17.3%) versus open (12.6%, 95% CI; 7.5–20.3%) TLIF. The authors appropriately cautioned that there was significant variability in reporting and a lack of clear definition as to what constituted a complication. In another review, Parker et al. assessed the infection rate between MIS and open TLIF and reported a significantly reduced rate for MIS (0.6%) versus open (4.0%) TLIF [60]. In a separate meta-analysis of 26 studies by Goldstein et al., there was no significant difference in reported surgical adverse events (p = 0.97), but MIS cases were significantly less likely to experience medical adverse events (risk ratio [MIS vs open] = 0.39, 95% confidence interval 0.23–0.69, p = 0.001) in patients undergoing minimally invasive TLIF/PLIF compared with open surgery [36].

Considering the current available literature, one could conservatively conclude that MIS fusion in the lumbar spine demonstrates superior perioperative quality and clinical outcomes and comparable midterm (1–2 year) radiographic and patient-reported outcomes. Although not supported by the current literature, anecdotal concerns of several up-front additional costs associated with MIS fusion (e.g., increased operative time during the learning curve, implant and disposable costs, dependence on the use of intraoperative imaging and associated resources, education and training, and a possible higher reoperation rate required for the removal of prominent or symptomatic implants) still remain. In the context of CER, the next logical step is to examine the CEA of MIS versus open fusion. In other words, one must determine the incremental cost of the demonstrated short-term perioperative benefits of MIS fusions.

3.4 Economic Comparison of MIS Versus Open Fusion

In a thorough review of this topic, Allen and Garfin note the increasing importance of CEA in our current healthcare environment. However, the authors point out the general lack of HEEs in the currently available literature [18, 32]. In addition, the authors point out a broader issue across all published HEEs in that a "consistent method of exactly which cost to include, and how to accurately measure direct and indirect cost is yet to be defined in spine care, and existing cost analyses of spine care vary widely in their methods of measurement" [32]. As noted previously in the section covering HEE, when assessing a CEA, the main drivers that need to be considered are the relative cost, or direct cost of index procedure, as well as ongoing costs of care postoperatively, and indirect costs and effect size and durability of the outcome gained.

In other surgical specialties, cost-effectiveness has been demonstrated in a limited number of studies comparing MIS and open surgical techniques. An example is provided by Bijen et al. in a systematic review of 12 randomized controlled studies that assessed the cost and effects of abdominal versus laparoscopic hysterectomy [61]. In this study, the authors demonstrated that although the total procedural costs were greater for MIS intervention (6.1% in this particular procedure), decreased length of hospital stay, fewer complications, and lower indirect cost compensated for the greater initial cost. As noted above, the perioperative direct cost for MIS lumbar fusion has been shown to be consistently lower then open fusion (Table 3.2). However, no randomized studies have included a HEE in the comparison of MIS techniques to open surgery or nonsurgical treatment of spinal disorders. More recently, economic considerations have been included in a handful of MIS versus open fusion observational studies; however, as noted in the recent systematic review by Goldstein et al. [55], the quality of evidence is generally low. Overall, the current comparative literature, albeit of limited quality, does suggest MIS fusion consistently provides significant short-term benefits and at least equal clinical outcomes. Consequently, demonstration of overall cost neutrality or cost saving from the perioperative benefits is paramount in justifying proportionally appropriate additional up-front cost.

3.5 Current MIS Versus Open Lumbar Fusion Health Economic Evaluations

As noted above, there is a general trend across most MISS vs. open HEEs of reduced costs and increased value associated with MISS compared to open surgery, despite similar patient-reported outcomes at follow-up. The decreased direct hospitalization costs have generally been attributed to reduced hospital LOS and decreased surgical service utilization; all the while implant-related costs seem to be comparable. In the table below, we have outlined some of the notable studies comparing MIS to open lumbar spinal surgery that have performed an HEE in some form or another (Table 3.2).

3.6 Current Limitations

A more accurate HEE requires the capture of other ongoing cost following discharge from hospital. No current study has assessed ongoing resource utilization beyond the perioperative period following MIS versus open spine surgery. As demonstrated in the recent CEA analysis from

Table 3.2 Overview of selected health economic studies comparing MIS and open spine surgery

Author/Year	Type	Economic perspective	Results of MIS	Results of open surgery	Summary
Wang et al. [29]	Retrospective cost analysis of one- and two-level interbody fusions	Hospital charges	One-level surgery, $70,159 Two-level surgery, $87,454	One-level surgery, $78,144 Two-level surgery, $108,843	The authors noted trends toward earlier discharge, reduced hospital costs, and reduced rates of transfer to inpatient rehab associated with MIS
Deluzio et al. [2]	Retrospective cost analysis of two-level PLIF	Hospital charges	Average total cost per procedure: $24,208.07 USD	Average total cost per procedure: $26,770.54 USD	Mean cost savings of $2563 associated with MIS over open surgery. Cost savings attributed with reduced hospital LOS, and decreased number of residual events
Pelton et al. [62]	Retrospective cost analysis of one-level TLIF in WC and non-WC patients	Hospital cost/direct implant cost	WC: $28,060 USD ($P = 0.0311$) Non-WC: $29,429 USD ($P = 0.0001$)	WC: $33,862 USD Non-WC: $32,998 USD	The authors noted statistically significant differences in total costs between the MIS and open cohorts, in both WC and non-WC patients. It was noted that the implant-related costs were higher in the MIS group; however, reduced healthcare resource utilization in this group compensated for increased cost related to implants
Rampersaud et al. [31]	Retrospective cost-utility analysis of one- and two-level MIS TLIF vs. open posterior decompression and instrumented fusion	Hospital/direct costs	Mean total direct cost, $14,183 CAD +/−3269.73(SD), ($P = 0.0009$). Mean change in health utility at 1 year, 0.113 QALYs (SD = 0.10).	Mean total direct cost, $18,663 CAD +/− 6197.32(SD). Mean change in health utility at 1 year, 0.079 QALYs (SD = 0.08)	Mean total direct cost of open fusion was 1.28 times greater than the MIS group ($P = 0.001$). At all time points, the cost-utility analysis favors MIS over open surgery
Gandhoke et al. [63]	Cost-utility analysis comparing MIS LLIF and open TLIF	Direct and indirect costs	Median total cost, $45,574	Median total cost, $44,068	When indirect costs were considered, the MIS group required an additional $35,347 per QALY gained compared to open
Vertuani et al. [64]	Cost-effectiveness analysis comparing OS vs. MIS TLIF	Direct costs of care	UK: Direct costs, 13,399 Euros Italy: Direct costs, 10,012 Euros Gain in QALYs for MIS, 0.72	UK: Direct costs, 15,065 Euros Italy: Direct costs, 10,985 Euros Gain in QALYs for OS, 0.68	MIS prevailed as the dominant strategy with lower costs per QALYs gained. In the sensitivity analysis, the same was true of most scenarios except those where the costs of MIS equipment rose above 4111 euros
Maillard et al. [65]	Retrospective cost-minimization study comparing OS and PO techniques	Total costs of hospitalization	Degenerative: Total cost of hospitalization—reimbursement = 1159.11 Euros gained TL trauma: Total cost of hospitalization—reimbursement = 1122.64 Euros gained	Degenerative: Total cost of hospitalization—reimbursement = 285.49 Euros lost TL trauma: Total cost of hospitalization—reimbursement = 1180.16 Euros lost	Overall, reduced hospital charges were noted in the PO group compared to the OS group. These differences were largely driven by reduced LOS in the PO group
Lucio et al. [66]	Retrospective cost analysis comparing open and MIS lumbar interbody fusion	Direct costs of care	Average total per-patient cost, $23,686.90	Average total per-patient cost, $25,272.31	Implant costs were higher in the MIS group by $3810.76 (27%), but remaining costs including OR services, surgical supplies were $2756.50 (56%) less in the MIS group
Parker et al. [67]	Prospective cost-effectiveness and cost-utility analysis of open vs. MIS TLIF	Direct and indirect costs of care	Mean total direct cost $27,621 +/− 6107(SD), ($P = 0.50$). Mean increase in QALYs over 2 years, 0.771	Mean total direct cost $28,442 +/− 6005(SD). Mean increase in QALYs over 2 years, 0.695	MIS TLIF was associated with a 1-day decrease in LOS ($P = 0.006$) which translated into cost savings of $1758 USD per case. The 2-year direct healthcare costs were comparable between the two groups ($P = 0.50$). Mean time for return to work was reduced less in the MIS group resulting in indirect cost savings ($P = 0.06$)
Singh et al. [68]	Prospective cost analysis comparing MIS vs. open TLIF	Direct hospital costs	Mean total direct cost, $19,512 +/− 4868 (SD), ($P < 0.001$)	Mean total direct cost, $ 23,550 +/− 3501 (SD)	Mean cost of open TLIF was $4038 (20.7%) more expensive than MIS TLIF. MIS TLIF was associated with decreased resource utilization compared to open TLIF at a statistically significant level
Sulaiman and Singh [69]	Cost analysis of open vs. MIS TLIF	Direct hospital costs	Mean direct hospital costs, $19,098 USD	Mean direct hospital costs, $37,681 USD	Significant differences in mean direct hospital costs were noted when comparing MIS vs. open TLIF ($P < 0.002$)

MIS minimally invasive surgery, *LOS* length of hospital stay, *PLIF* posterior lateral interbody fusion, *TLIF* transforaminal lumbar interbody fusion, *WC* workers' compensation, *QALY* quality-adjusted life years, *LLIF* lateral lumbar interbody fusion, *OS* open surgery, *PO* percutaneous osteosynthesis the 4-year SPORT data, ongoing cost, especially indirect cost, is significant following intervention for spinal disorders [14]. This was particularly noted for the degenerative spondylolisthesis (DS) subpopulation, where the largest ongoing cost occurred in the nonoperatively treated patients. Sustained clinical superiority and reduced ongoing cost enabled the ICUR for the surgically treated DS group to improve from $115,600 at 2 years (above 100 K cost-effectiveness threshold) to $64,300 per QALY at 4 years compared to nonoperative treatment. If the perioperative outcomes of MISS vs open spine surgery are more favorable, then the likelihood is that this also translates to reduced healthcare utilization cost in the short-term for MISS and needs to be affirmed or refuted. Related to postoperative healthcare cost, post-discharge adverse events such as deep surgical site infections requiring readmission or emergency department visits have not been captured. In the longer-term, revision surgery for other causes (e.g., instrumentation-related pain, pseudoarthrosis, or adjacent segment degeneration) should also be accounted for in MIS versus open lumbar fusion HEE models. Two recent reviews suggest that ongoing medical cost may in fact favor MISS. In the first study, Parker et al. aimed to determine the incidence of surgical sight infections (SSI) in patients undergoing MIS versus open TLIF reported in the literature and the direct hospital cost associated with the treatment of SSI following TLIF [60]. Ten MIS TLIF cohorts (362 patients) and 20 open TLIF cohorts (1133 patients) reporting incidences of SSI were identified. The cumulative incidence of reported SSI was significantly lower for MIS versus open TLIF (0.6% vs. 4.0%, $p = 0.0005$). At the institutional level, 120 open TLIF procedures, SSI occurred in six (5.0%) patients. The mean hospital cost associated with the treatment of SSI following TLIF was $29,110 in these six cases. The authors determined that the 3.4% decrease in reported incidence of SSI for MIS versus open TLIF corresponds to direct cost savings of $98,974 per 100 MIS TLIF procedures performed. In the second study, Wu et al. performed a meta-analysis looking at fusion rates between MIS and open TLIFs [59]. As noted earlier, the authors demonstrated equal fusion rates between MIS (94.8%) and open (90.9%) TLIFs. The authors also reported a difference in reported adverse events favoring MIS (7.5%) versus open (12.6%). Whether or not there is a significant difference in associated cost between revisions of an MIS vs open fusion remains to be evaluated.

The assessment of indirect cost, in particular, productivity losses (e.g., return to work and reduced out of pocket expenses for care givers and house work) is grossly absent in the MISS as well as overall surgical literature. Given the current findings, additional economic benefits likely exist for MISS. For example, the impact on improved time to productivity gains and other indirect economic benefits (i.e., from the societal perspective) associated with faster recovery is where we should be able to demonstrate further economic impact from MISS. With a demonstration of cost savings in the perioperative period, the promise of reduced morbidity from MIS of the spine to enable quicker return to activity, while many believe it to be true (the authors included), needs to be objectively assessed and the economic impact quantified. It is here where the true cost-effectiveness of MIS of the spine may garner the greatest support. The best example of this was demonstrated by Parker et al. [67]. The authors performed a prospective cost-effectiveness and cost-utility analysis of open versus MIS TLIF for grade 1 lumbar degenerative spondylolisthesis. In this study, 100 patients, 50 undergoing open TLIF and 50 undergoing MIS TLIF, were followed up from baseline until 2 years postoperatively. Consistent with other studies, MIS versus open TLIF was associated with a less hospital cost (mean $1758), and similar 2-year direct healthcare cost and quality-adjusted life years gained. However, the MIS group demonstrated reduced mean indirect cost of $8474, and total mean 2-year societal cost reduction of $9295 ($p = 0.03$) that was attributable to a quicker return-to-work compared to the open group.

3.7 Conclusion

Healthcare systems are constantly changing and introducing necessary reform to meet clinical demands while keeping growing financial concerns in check. Regardless of what changes occur in health reform, resource allocation will likely favor those interventions that demonstrate the best value. For clinicians to contribute to meaningful reform, insight into the decision-making language (e.g., HEE, cost per QALY gained) of the government, payers, and policy makers is crucial. Current comparative data (albeit of overall low evidentiary quality) suggest that MIS lumbar fusion provides at least equivalent clinical outcome in the midterm (1–2 years) and consistently demonstrates quality and cost-benefits in the perioperative period compared to open fusion. The initial increase in direct procedure-associated cost of MIS fusion appears to be offset by the perioperative benefits which produce an overall net cost savings. At present, the evidence is sparse and of low quality to enable any strong conclusions of superiority of MIS versus open from a clinical or economic perspective, however, the evidence is consistent enough to at least state non-inferiority. Going forward, more comprehensive HEE including longer-term patient reported outcomes, ongoing healthcare utilization following surgery, and perhaps, most importantly, the difference in indirect cost such as earlier return to activity (i.e., productivity) of MIS versus open spine surgery are required to support a broader adoption of MIS of the spine from a societal and payer perspective.

Summary

- As healthcare costs and burden of disease increase, it is increasingly important for researchers and clinicians to demonstrate value associated with costly interventions.
- A number of different types of HEEs exist, and depending on the question at hand, one may be preferable over another.
- The most rigorous type of HEE is a CEA, which simultaneously compares two interventions with respect to both cost and clinical effectiveness.
- Understanding the economic perspective of one's clinical or research question is crucial, and must be reflected in the study design. If a societal perspective is desired, more rigorous data collection methods must be employed in order to quantify the loss of productivity associated with an intervention.
- An appreciation for the general body of health economic literature in MISS is necessary to understand the strengths and limitations of our base of knowledge and necessary directions for future study. Going forward, capturing ongoing costs of care beyond hospital discharge and assessment of productivity losses may reveal the true economic benefits of MISS.

Quiz Questions

1. Which of the following would be considered a cost-minimization study?
   (a) A study comparing the costs associated with two different interventions.
   (b) A study comparing the costs associated with two different interventions, in whom the clinical outcomes have been consistently demonstrated to be different.
   (c) A study comparing the costs associated with two different interventions, in whom the clinical outcomes have been consistently demonstrated to be the same.
   (d) A study comparing two different interventions, which takes into account both costs and clinical effectiveness.
2. Which of the following scenarios would be most appropriate for a CEA?
   (a) Intervention A is more costly and more effective than intervention B.
   (b) Intervention A is more costly and less effective than intervention B.
   (c) Intervention A is less costly and more effective than intervention B.
   (d) Intervention A is more costly than intervention B, and the outcomes have been demonstrated to be equivalent.
3. Which of the following is an example of an indirect cost associated with an intervention?
   (a) In-hospital, transfusion-related costs
   (b) The lost work days incurred by the spouse of a patient, in order to care for that individual, post-discharge.
   (c) The cost of outpatient rehabilitation, post-discharge.
   (d) The costs related to treating a postoperative pulmonary embolus.
4. True or false: Generally, implant-related costs are greater in MISS compared to open spine surgery.
5. True or false: There exists an abundance of scholarship that has carefully studied the indirect costs of spinal surgery, both MIS and open.

Answers

1. c
2. a
3. b
4. True
5. False

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