Cost-Effectiveness in Adult Spinal Deformity Surgery

The complexity and heterogeneity of adult spinal deformity (ASD) creates significant difficulties in performing high-quality, complete economic analyses. For the same reasons, however, such studies are immensely valuable to clinicians and health policy experts. There has been a paradigm shift towards value-based healthcare provision, and as such, there is an increasing focus on demonstrating not just the value of ASD surgery, but the provision of care at large. Health-related quality of life measures are an important tool for assessing value of an intervention and its effect on a quality-adjusted life year (QALY). Currently, there are no definitive criteria in regard to assigning the appropriate value to a QALY. A general accepted threshold discussed in literature is $100,000 per QALY gained. However, this figure may be variable across populations, and may not necessarily be applicable in today’s economy, or in all healthcare economies. Fundamentally, an effective treatment method may be associated with a high upfront cost, however, if durable, will be cost-effective over time.

The emphasis on cost-effectiveness and cost-utility analysis in the field of adult spine deformity is relatively recent; therefore, there is a limited amount of data on cost-effectiveness analyses. Continued efforts with emphasis on value-based outcomes are needed with long-term follow-up studies.

KEY WORDS: Cost-effectiveness, Spine deformity

Abbreviations: ASD, adult spinal deformity; HRQoL, health-related quality of life; MIS, minimally invasive surgery; OR, operating room; QALY, quality-adjusted life year; SRS, stereotactic radiosurgery; VAS, visual analog scale

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dult spinal deformity (ASD) is a common disorder that presents a significant burden on our healthcare economy.1 In 1998, the Institute of Medicine defined healthcare priorities for research and funding based upon the burden of disease.2 ASD is an important societal priority based upon both the prevalence and the impact of disease.3,4 In a value-based healthcare economy, an evidence-based approach to the treatment of ASD requires analysis of cost, risks, and outcomes of care.

The application of formal economic analyses to the management of spinal disorders will provide a framework for incorporating cost, risk of care, resource use, and clinical outcomes. Multiple factors contribute to the complexity of decision making in resource allocation process. Furthermore, the management of spinal deformity in the adult is characterized by significant variability.5,6 Variability exists regarding operative and nonoperative approaches to care, and regarding specific operative strategies.7 The treatment of ASD often requires complex surgery that leads to significant cost and resource allocation.8 In the United States, annual expenditure for spine care is over $86 billion. There has been a steady increase in the number of ASD surgeries performed, as such resources have been allocated to manage these complex cases and represent a significant portion of that figure. Therefore, a practicing spine deformity surgeon must be mindful not only of the clinical effectiveness of the operation, but also the cost-effectiveness of corrective surgery over the course of a patient’s longitudinal care. In general, the healthcare system is slowly migrating to a value-based approach. It is important to consider the definition of “value” of different surgical treatment options in ASD. The value of an intervention is defined as the quality of the intervention divided by the cost of the intervention measured over time. Appropriate care is the management strategy that optimizes
outcome while limiting cost and risks of care. A thorough cost-effectiveness and utility analysis will detail the economic implications of care with clinical outcomes. In a value-based healthcare economy, cost of services should be supported by a benefit in clinical outcome. The purpose of this paper is to provide an overview of cost-effectiveness studies in ASD surgery, and to guide future studies for cost-effectiveness research in ASD.

UTILITY MEASURES

Outcome measurement is an important and effective way to quantify the end result of care and therefore the utility of care provided. Quality metrics are often limited to measures of process including rates of complication, length of stay, adherence to protocols, or readmissions and reoperations. There is a poor correlation between these measures of quality and measures of the patient’s healthcare experience. Patient centered metrics including general health status and disease-specific metrics are a more direct reflection of the patient’s healthcare experience, and more useful in guiding a value-based approach to care. There is a fundamental difference in quality measures that measure an individual provider’s performance and other patient-centered clinical outcome measures. Though quality metrics are important in assessing quality of healthcare, it provides limited input on its contribution to health-related quality of life (HRQoL). Independent of the economic implications of ASD management, patients living with ASD are debilitated by their disease process. The Global Burden of Disease Program reviewed the worldwide impact of common diseases on health status and disability and concluded that spinal disorders causing low back pain lead to more global disability than other common medical comorbidities. In the International Quality of Life Assessment Project, Pellisé et al reviewed almost 25,000 patients from 8 countries and demonstrated that patients with ASD self-reported significantly worse scores for pain, function, mental health, and social function than patients with other significant medical conditions such as arthritis, diabetes mellitus, pulmonary disease, and heart disease. As such, patient-reported outcome measures are imperative to assess the value that an intervention adds to a patient’s HRQoL. Several disease-specific and general health outcomes tools are frequently utilized to calculate utility scores (SF-36, EQ-5D, stereotactic radiosurgery [SRS], ODI). A utility score is a health status measure that quantifies the patient’s assessment of their condition, and based upon time utility trade-offs, can yield the value of quality-adjusted life years (QALY). A QALY measures the health state of the patient on a scale with zero the equivalent of death and 1 equal to the optimal state for 1 yr of life. The QALY of a certain treatment is calculated by multiplying the utility value of that treatment by the duration of treatment effect. An appropriate threshold of cost per QALY is not well-established, and may be dependent upon healthcare priorities and resources of specific populations.

COST-EFFECTIVENESS ANALYSES AND ASD

Cost-effectiveness analysis is a term that encompasses cost-benefit, cost-effectiveness, and cost-utility analyses. Each differs based on the specific outcome measures used. While all 3 typically measure cost in monetary units, cost-effectiveness and cost-utility analyses measure outcomes in disease- or condition-specific units of outcome and health status preference and QALYs, respectively. Cost-effectiveness analyses use natural units such as change in hemoglobin A1C, improvement in systolic blood pressure, or improvement in scores on a pain questionnaire to assess outcomes. While this facilitates the analysis of the study by using data that are likely readily available, it hinders comparisons to other studies that use different outcome measures. Finally, cost-utility studies, often considered the gold standard, measure outcomes using a construct called a health-state utility. These are most commonly referred to as QALYs as discussed above. Cost-utility studies are useful in comparing alternative treatments for specific conditions, and in comparing the value of interventions across medicine. Cost-utility studies provide important guidance for healthcare resource allocation. Unfortunately, the literature on spinal deformity surgery has a paucity of studies that detail both cost and outcome. The SPORT trial has provided useful information regarding cost-utility in common lumbar degenerative disorders, in which it demonstrated the 2-yr cost-effectiveness of decompressive laminectomies for spinal stenosis and discectomies for disc herniation at $77,600/QALY and $34,355/QALY, respectively. Meanwhile, lumbar fusions for spondylolisthesis were reported at $115,600/QALY at 2 yr and $64,300/QALY at 4 yr.

STUDIES IN SPINAL DEFORMITY SURGERY

Economic studies may be performed that capture and analyze resource use associated with spinal deformity surgery. In essence, these studies simply quantify the resources by type without converting dollars or other currency. While these studies, when performed rigorously, may provide an accurate accounting of the inputs associated with deformity surgery, variations in practice patterns and patient and other factors may limit the external validity of such investigations.

Hostin et al recently published the results of a multicenter study of inpatient resource use associated with ASD surgery. They found significant heterogeneity in resource use (blood products, amount of bone morphogenetic protein, and number of screws, rods, wires, and cages) between centers. Average bone morphogenetic protein use per center, for example, varied by up to the equivalent of 3 large kits. This study, however, is significantly limited by incomplete control for confounding patient-specific factors that may affect resource use, such as comorbidities, osteoporosis, and smoking. It does highlight one of the main limitations of many cost-effectiveness studies: variability in resource use and cost structures often limit the external validity of a study’s results. Description of costs alone had limited utility in
the absence of information on corresponding outcomes of care. Cost-minimization studies may yield insight into how to limit costs, but an evidence-based approach to spinal disorders requires consideration of the outcome implications of cost reduction.

Cost studies are a specific type of partial economic evaluation in which all resources are monetized. In addition to factors that can lead to variations in resource use discussed above, the cost of resources can vary significantly between geographical regions or between medical centers as well, further limiting the external validity of studies performed at one or a few centers. Pahlavan et al22 published a study of implant costs from 6 manufacturers at 45 academic medical centers. They found wide variation in costs for pedicle screws, anterior cervical plates, and interbody devices between centers. The presence of wide variation in implant costs is a clear reflection of a market economy in spine surgery that has significant barriers to transparency of costs, and obstacles to market competitive forces.

A simple comparison of costs associated with 2 or more interventions may be appropriate if certain criteria are met. Most importantly, the outcomes of the interventions should be comparable. Additionally, the groups should share a common diagnosis and/or treatment such that exchangeability of the cohorts is maximized. These conditions are so restrictive that Briggs and O’Brien23 argue that a cost-minimization analysis is only appropriate if a formal equivalence study has shown that the interventions are likely to produce similar outcomes.

The following case illustrates well the dissociation between quality metrics, cost, and outcomes. A 68-yr-old woman has a limited intervention that results in no improvement of HRQoL (Figure 1). She initially presents to an outside facility with sagittal and coronal plane deformity, and is debilitated by her imbalance. The patient is treated with a limited posterior spine surgery. In terms of quality metrics alone (length of stay, complications, reop/readmit at 90 d) the surgery is a success. However, there is no improvement in HRQoL. There is also no improvement in radiographic or patient-centered clinical outcomes, and the patient remains disabled. She goes on to a major revision surgery that involves more cost, risk, and potential for complications. But if this surgery results in a major improvement of her health status, then it is clearly a more cost-effective approach to care (Figure 2).

Glassman et al24 reported on the cost of nonoperative care for adults with spinal deformity in a prospective cohort of 120 adult scoliosis patients treated nonoperatively. Duration of use and frequency of visits were collected for 8 specific treatment methods: medication, physical therapy, exercise, injections/blocks, chiropractic care, pain management, bracing, and bed rest. Costs for each intervention were determined using the Medicare Fee schedule. Outcome measures were the SRS-22, SF-12, and ODI. Analysis was performed for the entire group, and for subsets of high (ODI > 40), mid (ODI = 21-40), and low (ODI < 20) symptom patients. In nearly half of scoliosis patients who received no treatment, the only significant change in HRQoL measures over the 2-yr period was in SRS satisfaction subscore (0.3 points,
$P = .014$). Among the 68 adult scoliosis patients who used nonoperative resources, there was no significant change in any of the HRQoL outcome parameters. Mean treatment cost over the 2-yr period was $10,815. Mean cost over the 2-yr period averaged $9704 in the low-symptom patients, $11,116 in the mid-symptom, and $14,022 in the high-symptom patients. Though this study was not randomized, the authors concluded that the substantial cost of nonoperative care yielded little clinical value.

In a retrospective, single-center study, Uddin et al.\textsuperscript{25} compared the hospital charges associated with minimally invasive and open surgery for patients with adult degenerative scoliosis. Although all patients in the study shared a diagnosis of adult degenerative scoliosis, careful examination of the study data reveals that the patients in the minimally invasive surgery (MIS) and open cohorts differed in potentially important ways despite the authors’ efforts to match them. The mean preoperative coronal Cobb angle for the open group was over 10° greater than for the MIS cohort. Perhaps related to this, or for other reasons not fully described in the paper, patients in the open cohort had a mean of 7.6 vertebral segments fused, whereas the MIS cohort had a mean of 4.4 segments fused. Patients in the open cohort had a higher (worse) mean baseline ODI score but at 2 yr postoperatively had a lower mean ODI score. Mean baseline visual analog scale (VAS) back and leg pain scores were similar between the cohorts, but the open cohort had better mean scores on both measures at 2 yr postoperatively. In this study, the 2 groups were different in regard to the magnitude of the deformity and the severity of the symptoms. The mean cost of the open cohort was greater than that of the MIS group ($392,000 vs $270,000). Furthermore, the equivalence of MIS and open surgery in adult degenerative scoliosis has not been demonstrated in a high-quality study performed for this purpose. The value of an improved postoperative VAS or ODI score in open surgery has not been well-defined, but in a value analysis, this outcome of surgery would be an important part of the comparison. For these reasons, the results of Uddin et al.\textsuperscript{25} do not allow strong conclusions regarding the relative value of MIS vs open surgery for ASD.

In a 2013 multicenter retrospective study, McCarthy et al.\textsuperscript{26} reported on 4 clinically and radiographically distinct groups of ASD and compared the cost of surgical treatment among the groups. Three hundred twenty-five consecutive ASD patients were categorized into one of 4 diagnostic categories of deformity: primary idiopathic scoliosis, primary degenerative scoliosis, primary sagittal plane deformity, and revision. Generalized linear regression models were used to analyze the direct cost of surgery and differences in costs across the 4 diagnostic categories considered. Significant differences were observed in direct cost of surgery for different categories of ASD, with surgical treatment for primary degenerative scoliosis being the most expensive followed by primary sagittal plane deformity, primary idiopathic scoliosis, and revision. They also found higher direct costs with increasing age, length of hospital stay, length of fusion, and fusions to the patient’s pelvis. There was also an incremental increase in cost of $4000 per level fused. Again, in the absence of information on outcomes of care, the difference in cost alone yields little insight into appropriate use of limited resources.

McCarthy et al.\textsuperscript{27} published a report of a cost analysis of ASD over time. The authors reported on 484 adults treated with surgery for ASD, with average follow-up of almost 5 yr. Total hospital costs averaged $120,394, with primary surgery averaging $103,143 and total readmission costs averaging $6,726 per patient with a readmission (n = 130 or 27% of all patients). Operating room (OR) costs averaged $70,514 per patient, constituting the majority (59%) of total hospital costs. Average total hospital costs across all patients significantly increased ($P < .01) after primary surgery, from $111,807 at 1-yr follow-up to $126,323 at 4-yr follow-up. Regression results also revealed physician preference as the largest determinant of OR costs, accounting for $14,780 of otherwise unexplained OR cost differences across patients, with no significant physician effects on all other non-OR costs ($P < .05).

Terran et al.\textsuperscript{28} published on projected cost-effectiveness at 5 yr for patients who underwent surgical treatment of ASD. In this study, direct costs that included both hospital and physician reimbursements were calculated based on Medicare reimbursement rates. Clinical outcomes included measures of SRS and ODI at baseline, 1, and 2 yr postoperatively. In a review of 541 patients, the projected average QALY at 5 yr was $120,311 based on 2-yr cost and HRQoL data. The mean total reimbursement of the entire set of patients was $37,050.90 exclusive of the cost of reoperations and $46,599.18 when factoring in the cost of reoperations. Calculation of health state utility values revealed that on average there was a cumulative gain in HRQoL. Thus, the projected cost per QALY decreased from $597,602.28 at year 1 to $120,311.74 at year 5 of projected follow-up. In this study, patients who underwent a revision or were likely to undergo a revision operation were identified, and their cost was doubled to account for projected increase in cost of care. The average cost/QALY at 5-yr follow-up was $120,311.74 with 41% of patients falling under the threshold of $100,000. In their study, more cost-effective patients had higher baseline ODI scores, lower baseline SRS scores, and shorter fusions. Patients with greater preoperative disability were more likely to reach cost-effectiveness as were patients with fusions of less than 8 vertebral levels. This paper, though very well done, had several limitations. Due to its retrospective nature, there is an absence of a comparative group. Several conclusions were made based on speculations and predictions. However, this study identifies potential future directions and study designs that would further illuminate this topic.

CONCLUSION

The management of spinal deformity is expensive, variable, and guided by limited evidence. An evidence-based approach to the management of spinal deformity will benefit from...
HRQoL-guided economic analyses. Comparative cost-effectiveness studies require transparency in resource utilization and patient outcomes in a single formal analytical structure. Surgery for ASD is associated with high cost and complication risk. Patient satisfaction with these procedures is high, suggesting that the risk/cost to benefit of surgery in spinal deformity may support costly and risky interventions. The effect of ASD surgery on HRQoL has been well documented, but the cost associated with changes in health status has not been well defined. The purpose of this paper was to describe the different types of partial and complete economic analyses and offer a critical review of examples of each in various ASD study populations. The complexity and heterogeneity of ASD creates significant difficulties in performing high-quality complete economic analyses. For the same reasons, however, it makes such studies valuable to clinicians and health policy experts. As a result of the paradigm shift towards a value-based healthcare economy, there must be focus on demonstrating not just the value ASD surgery but all aspects of medical care. HRQoL measures are an important tool for assessing value of an intervention and its effect on a QALY. Currently, there are no definite criteria in regard to assigning the appropriate value to a QALY. A generally accepted threshold discussed in literature is $100,000 per QALY gained. However, this figure may be variable across populations, and may not necessarily be applicable in today’s economy, or in all healthcare economies. Fundamentally, the cost-effectiveness of a treatment can be found in the durability of its outcome, even if the intervention is initially costly. The emphasis on cost-effectiveness and cost-utility analysis in the field of ASD is relatively recent; therefore, there is a limited amount of data on cost-effectiveness analyses. Continued efforts with value on basis-outcome studies are needed with long-term follow-up studies. Though great progress has been made since the notion of outcomes measures was first suggested by Dr Codman, high variability in ASD surgery has generated a lack of consensus on optimal cost-effective treatment strategy. An emphasis on value-based care in ASD, with time, will provide further insight on an optimal strategy for cost-effective care.

**Disclosure**

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

**REFERENCES**