An Economic Evaluation of Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis (AIS)

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Introduction:

Rising healthcare costs in the United States have led to increased scrutiny of elective procedures in healthy adults and children.[1] With annual health care expenditures estimated to be more than 100 billion dollars,[2] spinal disorders get particular scrutiny because they are so expensive to treat. Some have suggested that the natural history of AIS is not terribly negative, with only minimal impact on functional activities compared to the general population.[3] Thus, the overall value of spinal fusion procedures in healthy adolescents is unclear, and could be perceived as cost-inefficient.

To the best of our knowledge, there are no published studies that examine cost-benefit tradeoff of the surgical management of AIS while accounting for uncertainty in costs and gains. This study seeks to evaluate whether surgical intervention for AIS is cost-effective for patients who elect to undergo a spinal fusion procedure.

Material and Methods

Cost Determination

Costs are defined as the sum of direct costs associated with the post-operative hospitalization plus the professional fees for the surgeon and anesthesiologist. Indirect and opportunity costs were not included. To derive the mean and interquartile (IQR) range for hospitalization costs, itemized cost values reported in a recent cost-analysis by Kamerlink et al[4] were used. Differences in cost related to severity of curvature are accounted based on Lenke-type curve prevalence in the general population.[5] Physician fees were estimated from the CMS 2012 physician fee schedule for CPT codes 22802 (posterior arthrodesis for spinal deformity), 22843 (posterior segmental instrumentation), and 00670 (anesthesia for extensive spinal procedure). Billing for anesthesia services was based on an average procedure time of 338 minutes.[6]

Health Related Quality of Life (HRQL)

A literature search was conducted on the PubMed database using the key words, "adolescent idiopathic scoliosis quality of life", "adolescent idiopathic scoliosis HRQL", and "adolescent idiopathic scoliosis effectiveness". The search identified fourteen studies examining postoperative changes in HRQL attributed to surgery.[7-20] These studies measured quality of life in AIS patients using the SRS24, SRS22 or SF36 survey instruments. The scoring used by different instruments was normalized to a scale of 0-1, with 0 representing death and 1 representing perfect health.

Average Cost per QALY ratio

The ratio was calculated by dividing total costs by QALY gains accumulated over the lifespan. This was considered to be the base case. We used the standard discount rate of 3% per annum.[21] Two-way sensitivity analysis is then built upon to base case to allow the cost and QALY gain inputs to take on a range of values spanning the IQR for each variable. This was done to stress test the model to determine cost per QALY ratio in less favorable conditions.

Monte Carlo Analysis

Next, we introduced new variables, including additional costs and the impact on QALY gains resulting from surgical site infection (SSI) or death into the model. Compared to literature, chance of successful surgery and the chance of developing an infection are deliberately estimated to be somewhat lower and higher, respectively.[32,33]

Namely, probability of complication-free surgery is 90% +/− 10%. Of those who sustained a complication, an estimated that 90% +/− 3% is accounted for by infection. Each infection is estimated to add $10,000 in costs with a standard deviation of $2,000.[34] We also attribute to infected cases a hypothetical range of 30% +/− 10% loss in QALY.

This model was simulated 1000 times, representing 1000 hypothetical patients, with each case visualized as a dot in Figure 2.

All analyses above were performed using TreeAge Pro 2012 (TreeAge Software, Williamstown, Massachusetts) and summarized in a decision tree in Figure 1. Data inputs for the model are summarized in Table 1.

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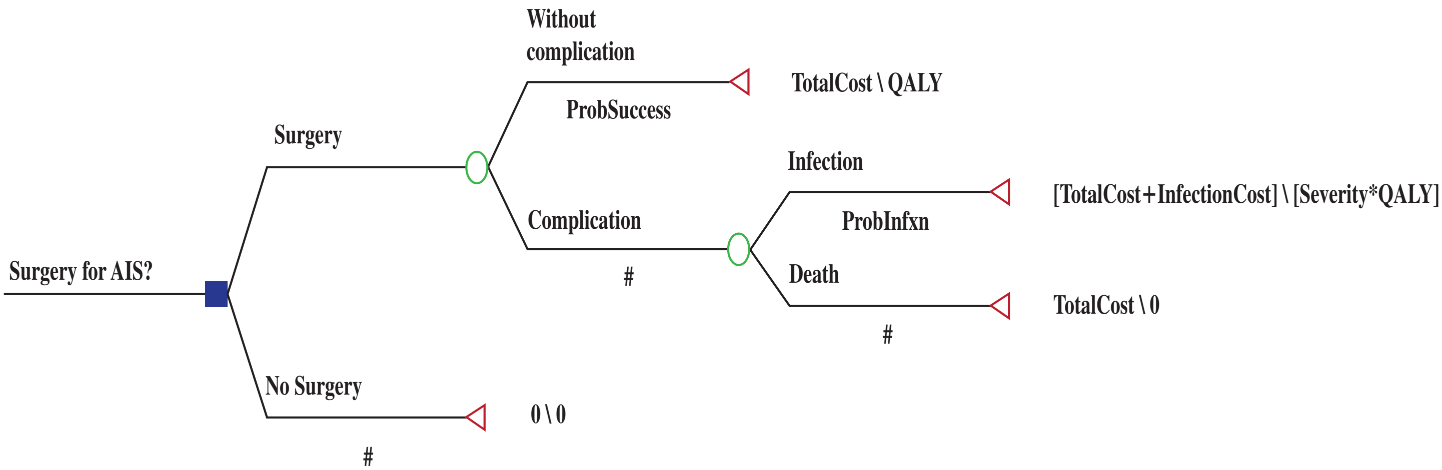

Figure 1. Decision tree used in the analysis for the Monte Carlo Analysis, please note that an additional "Infection Cost" variable is added. "Severity" variable represents the loss of QALY due to infection. The cost and QALY gains of each state will be summed across life expectancy with standard discount rate.

Table 1. Cost Analysis Model Inputs

		Median/mean	Low	High	References
Costs (dollars)					
	Anesthesiologist fee	$822			CMS Fee Schedule 2012
	Surgeon fee	$2,935			CMS Fee Schedule 2012
	Hospital fee	$32,029	$28,018	$36,922	4
	Total Cost	$35,786			
Utility (Quality of life)					
	Preoperative	0.764			8, 16-20
	Postoperative	0.843	0.82	0.864	7-20
Discount Rate		3%			21
Patient Characteristics					
	Life Expectancy (yrs)	78.1			WHO
	Age at initial operation	14.3			8, 16-20

Results

In the base case analysis, having a spinal fusion for AIS yields an overall gain of 2.22 QALYs and cost of $35,786, which yields a cost per QALY ratio of $16,114 per QALY. When subjected to two-way sensitivity analysis by varying both costs and QALY over the IQR, the range of average CER was $10,167 to $40,133.

Using Monte Carlo simulations in Figure 2 to model the hypothetical impact of infection or death, decision to undergo surgery is below the threshold of $50,000 per QALY greater than 99% of the time.

Discussion

As demonstrated by our base case estimates, the ratio of $16,114 per QALY is below the traditional $50,000 WTP threshold,[29] and when compared against other surgical interventions in orthopaedics, [24] the surgery for AIS ranks favorably.

Given potential uncertainty in cost and HRQL, we stressed the model using two methods. First, we employed two-way sensitivity analysis to account for variation in both cost and HRQL; and second, we used Monte Carlo analysis to simulate the impact of a hypothetical complication. From the model,

Cost-effectiveness of Surgically Managing AIS

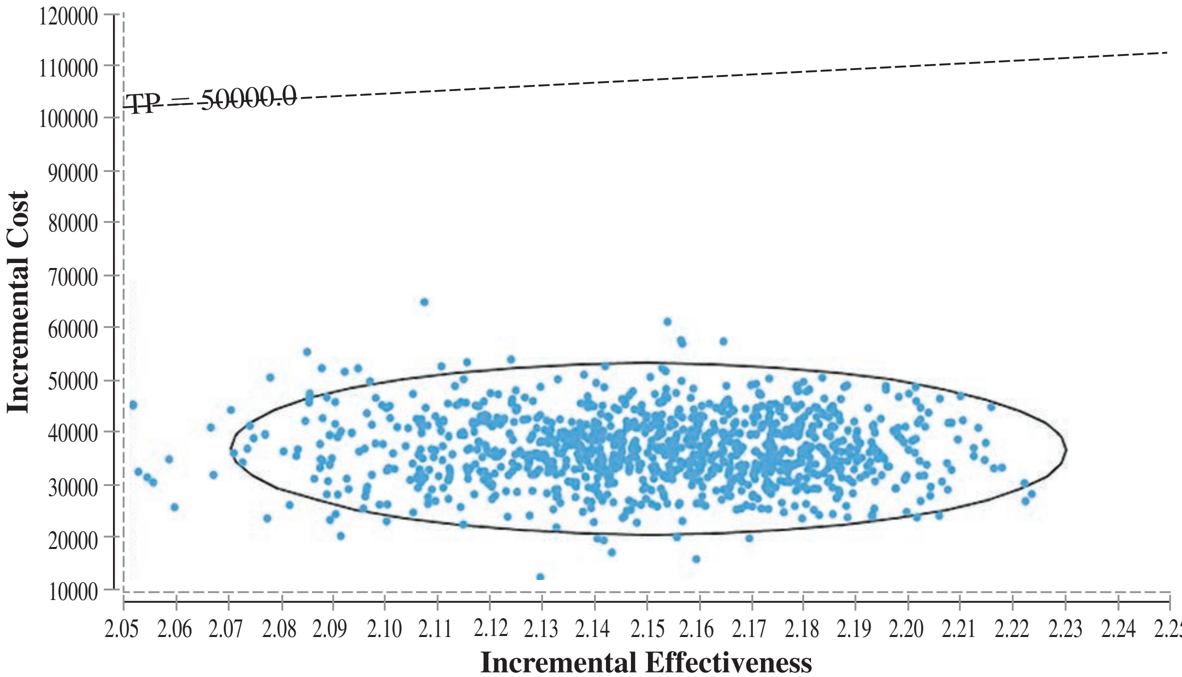

Figure 2. Scatter plot depicting the cost per QALY ratios derived from the Monte Carlo sensitivity analysis. Each dot represents the expected cost and QALY gains associated with a decision to undergo surgery, which is simulated 1000 times. The ellipse represents the 95% confidence ellipse for 1000 trials performed. The dashed line indicates the standard $50,000 per quality-adjusted life-years (QALY), below which the decision for surgery could be considered favorable.

even an operation with higher cost due to complication and lower QALY gains due to infection could achieve a ratio less than the benchmark of $50,000.

There are a few limitations to this study. First, costs attributed to surgery were based on a single-center study by Kamerlink et al.[25] In their study, success rate was high with few readmissions, and cost variability was mainly attributed to differences in Lenke curve types. We recognize that these costs may vary by location, complication rates, and other downstream costs.

Second, physician fees may depend on geography, hospital contracts with payers and hospital payment procedures. This study attempted to use standardized national CMS data to broadly reflect a nationally representative cost, but may not be representative for a specific patient living in a specific locale.

Third, all data used are derived from retrospective observational studies. Lack of high quality data on cost and outcomes continues to be a challenge. Fortunately, SRS questionnaires are validated and accepted instruments for measuring quality-of-life in AIS patients.[30,31] While data from these studies were not summarized using traditional meta-analysis methods, we feel that they provide an accurate estimate of the population level QALY gains.

Conclusion

Despite these limitations, this study is the first to use standard cost-analysis methodologies to provide a general estimate of the cost per QALY ratio of surgery in AIS. Our data demonstrates that the surgical management of AIS is cost-effective by traditional healthcare standards. As more comprehensive data on downstream costs, family burden, and complication rates become available, these models can serve as a framework for ongoing value analyses of AIS operations.

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