16 The Cost-Effectiveness of Various Surgical Procedures in the Cervical Spine

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Introduction

As the cost of healthcare in the United States continues to grow, a focus on the value of the actual healthcare provided has intensified. To determine the value, many cost-effectiveness analysis (CEA) studies are being employed to help guide practitioners to provide safe, economically viable care.

The cost of spine surgery is rising exponentially as are most aspects of healthcare in the United States. It was recently reported that the overall expenditures on degenerative spine care in the United States will exceed $85 billion dollars in a single year [1]. Without question, this yearly figure has risen since the time of that report.

Marked improvements in the care of the degenerative cervical spine pathologies have occurred over the last few decades. There are multiple approaches to the treatment of cervical spine pathology, each of which provides a similar clinical result. To be responsible providers of healthcare, it is imperative that spine surgeons not only assess the quality of each of these interventions but also determine the value the procedure brings to the patient and to society.

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Value

Value is defined as the overall quality of a good or service divided by the cost. In healthcare, value is commonly described as the health outcomes achieved per dollar spent [2].

$$\text{Value} = \frac{\text{Quality}}{\text{Cost}}$$

It is important to note that the actual value of healthcare increases with either an increase in quality or a decrease in cost. In surgical specialties, the cost of the procedure itself is not the only variable in the denominator of the value equation. Rather, all inpatient and outpatient preoperative, perioperative, and postoperative costs need to be included in the denominator to truly understand value. Utilizing a less expensive or less efficacious surgical procedure at the expense of higher direct and indirect perioperative costs does not actually realize any savings for the healthcare economy.

To quantify the quality of an intervention, researches utilize quality-adjusted life years (QALY) as a standard unit of measure. Researches use QALYs to measure the impact a specific procedure has on overall health. A single QALY gained implies 1 year of perfect health. Death equates with zero QALYs. These values are typically derived from the common HRQOL forms, such as the SF-36, EQ-5D, or PROMIS, that are often found in spine clinics today.

Two principal means of value analysis in healthcare are cost-effectiveness analysis and

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cost-utility analysis. Cost-effectiveness studies rely on a fixed outcome and cannot quantify the subjectivity of different patients that have a similar clinical outcome. Cost-utility analysis, alternatively, relies on QALYs to impart a patient-centric view on the outcome of an intervention.

In spine surgery, it is not only important to perform the procedure that gives your patient the best outcome. Surgeons also need to realize the overall value of the procedures they are performing. With simple, degenerative cervical spine surgery, there are often at least two surgical approaches for each problem – an anterior or posterior approach. Researchers rely on the incremental cost-effectiveness ratio (ICER) to help delineate between the utility of two interventions for the same underlying diagnosis. The ICER utilizes a ratio comparing the cost of a given intervention to the quality of life years gained. In essence, it is comparing the value of two interventions.

$$\text{ICER} = \frac{\text{Cost of surgery A} - \text{Cost of surgery B}}{\text{QALY of surgery A} - \text{QALY of surgery B}}$$

This formula reflects the actual cost of the additional QALYs provided by one procedure in comparison to another. For example, there are three different surgical procedures for treating cervical radiculopathy: foraminotomy, ACDF, and cervical disc replacement.

Intervention	QALY gained (all hypothetical)	Cost (all hypothetical)
Foraminotomy	2	$1000
ACDF	2.2	$1500
Cervical disc replacement	2.5	$2000

To calculate the ICER, we want to determine the incremental cost of an ACDF compared to a foraminotomy.

$$\text{ICER} = \frac{\text{Cost of surgery A}(\$1500) - \text{Cost of surgery B}(\$500)}{\text{QALY of surgery A}(2.2) - \text{QALY of surgery B}(2)}$$

$$\text{ICER} = \frac{\$500}{0.2}$$

$$\text{ICER} = \$2500$$

The incremental cost, in this example, of utilizing an ACDF versus a foraminotomy is $2500 per QALY. Using the same idea and calculations, the incremental cost of a cervical disc replacement versus an ACDF is $1666 per QALY. Utilization of this type of analysis allows for healthcare dollars to be spent on the most efficient and valuable interventions.

Once the value of a medical intervention is determined, it is then important to determine whether that cost/QALY is within the societal threshold. In the United States, $50,000 is generally the value placed on a single QALY [3].

Ambulatory Surgery Centers and Outpatient Surgery

As healthcare continues to evolve, the economics of medicine are one of the overwhelming drivers of change. Medical treatment in large, tertiary hospitals is not always the most efficient for the patient and is frequently more expensive than potential alternatives. Both surgeons and payers are always looking for medically equivalent, yet less expensive, alternatives.

Over the past decade, the advent of specialized, ambulatory surgery centers (ASCs) has provided an alternative surgical avenue for indicated surgical procedures compared to the traditional hospital-centric paradigm. The goal of an ASC is to take outpatient surgical procedures out of the hospital setting to save on both time and costs. These centers are said to both increase efficiency while maintaining the high level of quality seen in a traditional hospital.

As spine surgery has become less invasive, the opportunity to utilize ASCs has increased. There is ample evidence in the lumbar spine literature suggesting that lumbar discectomies and

decompressions can be done safely in an outpatient setting while also providing close to a 30% cost savings [4]. The overall complication rate of cervical surgery done in ambulatory care centers has also been studied and found to be quite low [4–6]. In one large study detailing outpatient one- and two-level anterior cervical discectomy and fusion (ACDF) procedures, the overall complication rate was less than 1%. Out of 1000 patients, only two patients developed prevertebral hematomas which were both managed safely [4]. Overall, outpatient anterior cervical discectomies have very low readmission and complication rates [6]. Based on these cost-saving studies, it has been suggested that moving applicable ACDFs to an outpatient setting could save the total healthcare economy more than $100 million annually [5]. Considering that the cost is in the denominator of the value equation, any decrease in the cost will result in an inversely proportional increase in value.

Cost is clearly associated with the specific physical location a procedure is performed. Location on a more global scale also plays a role in the overall cost-value relationship. Throughout the United States, cost varies significantly by the geographic location. At the state level, costs can vary by up to 129% from the least to the most expensive state [7]. Consequently, the geographical location of a study cannot be ignored as a 100% difference in price would clearly skew the overall value calculated for a given intervention.

Radiculopathy

There are two surgical approaches to the treatment of cervical radiculopathy: anterior or posterior. A posterior cervical foraminotomy was the gold standard in the treatment of degenerative cervical radiculopathy for many years. Over the past few decades, the anterior cervical discectomy and subsequent fusion has become the most utilized procedure for cervical radiculopathy. The cervical artificial disc was conceived and developed as literature began to accumulate detailing possible adjacent segment degeneration/disease potentially originating from motion segment loss after an ACDF. If each of these interventions is considered to have a relative clinical equipoise, then the overall cost of the respective surgical technique will be of great importance in determining its value.

Both ACDF and CDR procedures are cost-effective [8–12]. Both procedures have a cost/QALY ratio of less than $50,000 [8]. There are numerous studies comparing the cost-effectiveness and overall value of these surgical interventions. As previously mentioned, all of the published reports conclude that both procedures are cost-effective and efficacious; however, there are conflicting conclusions as to which procedure actually provides the most value to the patient and to society.

Qureshi et al. reviewed the cost-effectiveness of single-level ACDF versus single-level CDR for the treatment of cervical radiculopathy. They assumed a 5% rate of pseudoarthrosis and hardware failure in the ACDF group as well as a 3% rate of adjacent segment degeneration. They utilized a 1.5% hardware failure rate in their model for the CDR cohort. Interestingly, even if a 5% rate of pseudoarthrosis and a 3% rate of adjacent segment degeneration are accurate estimates, most of the patients with these complications are neither symptomatic nor need further surgical intervention, thus complicating this analysis. Utilizing previous studies of CDR and ACDF, each procedure was given a specific utility value (a value of 1 is perfect health and a value of 0 equates to death). An ACDF was given the value of 0.8, and a CDR was given the value of 0.9. In this study, the total lifetime cost of a CDR was $4836 less than an ACDF. A CDR was seen to generate 3.94 QALYs, while an ACDF only provided 2.02 over a patient's lifetime. Given this data, the overall cost-effectiveness ratio of a CDR in this specific clinical scenario was $3042 per QALY, while an ACDF required $8760 per QALY. In this instance, the ICER is -$2394 in favor of the CDR, implying that CDR is both less costly and more effective than the alternative.

Warren et al. studied a randomized patient population undergoing either a single-level ACDF or a single-level CDR. They found that, while both an ACDF and CDR are cost-effective

procedures, the cost/QALY analysis in their study favored the ACDF even though the ACDF was a more costly procedure. Interestingly, there were no revisions in this ACDF cohort, which would cause the data to vary greatly when compared to studies that are assuming a 5% reoperation rate [13].

Another study from McAnany et al. reviewed the 5-year cost-effectiveness of ACDFs and cervical disc replacements. Their data revealed a cost per QALY difference of nearly 7000 dollars favoring CDR. Per their report, as long as complication rates can be kept below a threshold value of 4.4%, then CDR is the dominant technique for a single-level radiculopathy. Interestingly, the QALYs gained are not statistically different. However, the overall cost is nearly 20,000 dollars higher over 5 years in the ACDF subgroup [10].

Ament et al. studied 330 patients with two-level degenerative disc disease randomized to either undergo a two-level CDR or a two-level ACDF with 5-year follow-up. They attempted to calculate QALYs for each cohort. In terms of direct cost, the CDR costs $1687 more than a comparable ACDF over a 5-year period. However, the CDR cohort had significantly less productivity loss, $34,377, when compared to the ACDF group given a markedly different return to work rate. In this study, the ICER for a CDR is -$165,103 per QALY from a societal perspective and $8518 from a health systems perspective [14].

Given the upfront costs of a cervical disc replacement and the cost of a revision, it has been shown that for a CDR to be cost-effective it must last more than 7 years [9]. In addition, the reoperation rate must stay below 10.5%. Most of the current literature shows the overall reoperation rate for CDR to be much less than this cutoff value of 10.5% [15]. However, in patients over 65 years old, the reoperation rate after a CDR rises to 13% [15]. In this patient population, both an ACDF and a foraminotomy would seem to be a more cost-effective intervention.

In addition to the anterior decompression of neural elements, posterior decompressive surgery is a viable option for the treatment of radicular pain. Anecdotally, many surgeons deride the posterior cervical foraminotomy (PCF) option when evaluating a patient for surgical intervention. However, ACDFs are much more expensive than a single-level foraminotomy for the treatment of cervical radiculopathy yet provide a very similar clinical outcome [16]. The increased operative costs of the ACDF are chiefly driven by the cost of instrumentation and the difference in length of stay [16].

Tumialan et al. studied the cost-effectiveness of the PCF compared to a single-level anterior cervical discectomy and fusion in a military population. In this study, both the direct and indirect costs of the foraminotomy were far less than the ACDF [17]. The direct surgical costs for the ACDF were $6508 more than the PCF. The indirect costs were calculated to be between $13,585 and $24,045 greater in the ACDF group. Again, similar to the CDR data, the patients undergoing the arthrodesis were kept out of work for an average of 14.8 weeks longer than the patients in the PCF group. Cleary this will skew the overall value equation. In regard to long-term costs, the reoperation rates for ACDF and PCFs are very similar [18]. Another recent study showed ACDFs to cost $11,757 more than a PCF for the actual index procedure itself and another $11,420 over the first 30 postoperative days [19].

Myelopathy

There is no question that the surgical treatment of degenerative cervical myelopathy (DCM) is cost-effective [19, 20]. Regardless of the severity of the disease, surgical decompression of the spinal cord results in improved function and quality of life. It has been shown that without surgery, 20–62% of patients worsen over a 3–6-year period. Surgery has been shown to provide a long-lasting, significant improvement for the patient at an acceptable cost [19]. All the accepted treatments of CSM (anterior cervical corpectomy and fusion, laminoplasty, laminectomy with fusion) have been found to have similar neurologic outcomes [21].

Compared to radiculopathy data, there is a paucity of data examining the value of anterior versus posterior surgery for CSM. Ghogawala

et al. undertook a small pilot study looking at 50 patients with CSM treated with either anterior or posterior decompression and arthrodesis. As expected, both groups had a similar improvement in neurological function after surgery. However, the hospital costs for the posterior fusion group were significantly higher, $29,465 versus $19,245. No indirect costs or direct costs relating to postoperative care were calculated in this study, limiting its overall usefulness [22].

Whitmore et al. conducted a similar study. They used two different models to assess the value of each intervention. One method revealed overall direct hospital costs were $27,942 ± 14,220 versus $21,563 ± 8721 for the posterior cervical fusion and the ACDF, respectively. Using a different mechanism of assessing direct costs, there appeared to be no difference in overall hospital costs between the two procedures [23]. However, even with similar costs, given the slightly improved outcomes in the anterior group, the overall ICER is in favor of ACDF.

Laminoplasty has been shown to have equivalent outcomes to ACDF in the treatment of CSM [24]. Unfortunately, given the overall rarity of cost-effectiveness data on cervical spine interventions, no studies to date have been performed examining the actual value of a laminoplasty compared to other possible interventions in the cervical spine.

Discussion

As the US government and payers move from a fee-for-service payment schedule to a more value-driven system, the need for cost-effectiveness analyses will increase greatly. Although much data exists comparing the efficacy of specific surgical interventions, little data actually exists showing the value of these interventions in the cervical spine.

Much of the cost-effectiveness debate in the cervical spine literature focuses on the cost and value difference between an anterior cervical discectomy and fusion and a cervical disc replacement. There is literature supporting the superior value of each technique over the other.

Much of the literature advocating the superior value of the CDR over the ACDF comes from the initial, randomized clinical trials sponsored by the device companies and administrated by the physicians who helped design the devices and who may be investors in the companies themselves. This obviously imposes a potential source of bias on all of the data. In addition, the patients in these studies were perfectly screened. As new products make their way out into the community and away from these stringent surgical requirements, the initial excellent results may not be reproduced. This might be the case with CDRs. Recent research outside the realm of the IDE studies seems to indicate increased rates of heterotopic ossification than previously reported and equivalent levels of adjacent segment disease when compared to ACDFs [25–29]. In one study, the rates of surgical revision were actually higher in the CDR group [30]. This would greatly confound the value data that currently suggests a CDR is a more valuable procedure than an ACDF. As much of the data on CDRs originates from IDE studies that employ ideal indications for surgery, the studies themselves favor successful results.

There are other confounding variables within the CDR studies that could possibly alter the results of a cost/value analysis. Some of the data suggesting that the CDR is a more valuable procedure relies on the fact that the surgeon's fees for this procedure are markedly lower than for an ACDF [15].

In addition, the speed at which patients return to work appears to be one of the more important variables affecting the overall value of these procedures. CDR patients had a much higher return to work rate when compared to ACDF patients [14]. One study even showed that CDR patients returned to work 38 days quicker than ACDF patients [31]. A quicker return to work leads to markedly lower indirect costs. Interestingly, this phenomenon appears to be completely surgeon generated as there is no good data regarding the appropriate timing for return to work after either of these procedures. One could argue that surgeons are iatrogenically inflating the long-term costs of an ACDF by requiring the use of rigid

collars and keeping patients out of work for extended periods of time. The use of a rigid collar is a significant impediment to return to work after an ACDF, and current literature does not support the use of a collar in one-level fusions [32].

A foraminotomy has been shown to be much more cost-effective in a population of people with a physically demanding job. Aside from the difference in cost between a foraminotomy and any instrumented procedure, much of the cost savings revolve around the quicker return to work. In cases of single-level cervical radiculopathy, a foraminotomy demonstrates clinical equipoise to an ACDF (and thus a CDR) while providing improved short-term (due to lack of instrumentation) and long-term costs given the similar revision rates and quicker returns to work.

Conclusion

Given the state of modern healthcare, it is imperative that all medical interventions not only be scrutinized for their success rates but also for the overall value. ACDFs, CDRs, and PCFs are all viable options for the treatment of one-level cervical radiculopathy. Currently, both a CDR and PCF appear to be more valuable interventions for properly indicated patients. However, newer research does seem to question the initial value improvement espoused by CDR supporters. Overall, there is a dearth of literature looking at the value of cervical spine surgery. The few papers that exist contain potentially significant bias and also do not portend a consistent means of measuring value. As with all academic endeavors, more research needs to be done.

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