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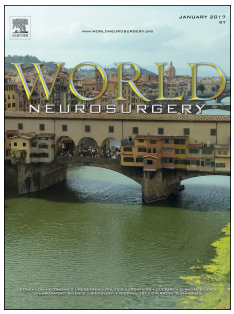

Financial Aspects of Cervical Disc Arthroplasty: A Narrative Review of Recent Literature

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Short Title: Cost-effectiveness of CDA

Key Words: cervical disc arthroplasty; anterior cervical discectomy and fusion; cost-effectiveness; cost-analysis studies

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Abstract

Recently, there is significant interest in understanding the cost-effectiveness of treatments in spine surgery as healthcare systems in the United States move towards value-based care and alternative payment models. Previous studies have demonstrated comparable outcomes of cervical disc arthroplasty (CDA) and anterior cervical discectomy fusion (ACDF); however, there is a lack of consensus on the cost-effectiveness of CDA to support full adoption. Limitations of these cost-analysis studies also exist in the literature including industry-funding, potential selection bias, and varying methods of calculating value. The goal of this narrative review is to provide an overview of the cost-effectiveness of CDA compared to ACDF and potential limitations with cost-analysis studies in spine surgery.

Introduction:

Although cervical disc arthroplasty (CDA) has been an available surgical alternative for many years throughout the world, and for over a decade in the United States, complete adoption of CDA in place of anterior cervical discectomy and fusion (ACDF) has been slow due to persistent controversies regarding long-term clinical outcomes, prosthesis survival, and cost-effectiveness.[1–3] Currently, indications for CDA include patients with either single or two-level cervical myelopathy or radiculopathy, who have failed conservative treatment, with limited instability and decreased degree of kyphosis.[4–10] The initial Federal Drug and Administration (FDA) Investigation Device Exemption (IDE) trials demonstrated positive clinical outcomes of CDA compared to ACDF in patients with cervical myelopathy and/or radiculopathy.[5,6,9,11–15] Additionally, long-term follow-up studies have demonstrated favorable results of arthroplasty, particularly in terms of pain, disability, neurological status and patient satisfaction.[16–22] Moreover, past studies have also reported decreased rates of radiographic adjacent segment degeneration and symptomatic adjacent segment disease after CDA compared to ACDF.[11–13,17,23–27] Although these studies have described encouraging results, some reports have noted limitations with generalizability, and elevated risks of selection bias due to the initial industry-sponsored trials' strict inclusion and exclusion criteria.[10,28]

In terms of revision and readmission rates, CDA appears to perform similarly, if not better, than ACDF.[17,21–24,26,29,30] While some studies have demonstrated decreased rates of reoperation at the adjacent level after CDA, Kelly and colleagues noted no significant difference in secondary surgery when comparing arthroplasty to ACDF up to 5-year follow-up.[21–23,29] Similarly, Bhashyam et al reported no significant differences with reoperation rates between ACDF and CDA.[30] However, the authors did find a higher readmission rate after ACDF that they

attributed to the difference in age groups of each cohort.[30] In contrast, Skeppholmm et al reported higher rates of reoperation after CDA compared to ACDF, likely due to implant migration as both groups had no significant difference in reoperation due to adjacent segment disease.[31] Consequently, as illustrated by these observations, CDA seems to be a viable alternative to ACDF in the right patient population.

Cervical disc arthroplasty does exhibit features supporting its increased use, including the noted ability to restore segmental mobility and observed increased return-to-work rates compared to ACDF.[5,15,32–38] Yet, other studies have argued that deterrents for the use of CDA include doubts surrounding its cost-effectiveness, as well as concerns with reimbursement and insurance coverage.[2,39] As noted above, despite reports showing comparable outcomes between CDA and ACDF, there continues to be a lack of consensus on the cost-effectiveness of CDA to justify its increased utilization. The purpose of this narrative review is to highlight the most recent literature analyzing the cost-effectiveness of CDA compared to ACDF including potential limitations of current cost-analysis studies.

Overview of Terminology and Cost-Analysis Studies*:*

As healthcare systems aim to move towards value-based care with alternative payment models, various cost-analysis methods have been employed to determine the most cost-effective procedures.[40–43] Cost-effective analysis studies (CEA) are used to evaluate the cost-effectiveness of different treatment interventions.[41,43,44] Additionally, cost utility analysis (CUA) employ health utility measures to compare the cost-effectiveness of two treatment interventions.[41,43–45] To assess the value and quality of care, patient-reported outcome measures (PROMs), such as the Short-Form 6-dimensions (6D) and 12-item (12) or the EuroQol Five Dimension questionnaire

(EQ-5D), are used. These PROMs provide an estimate of the quality-adjusted life-year (QALY) gained by patients over time for specific interventions.[45–49] Alternatively, the health state utility score (HSU), particularly used in CUAs, is another method for measuring value and quality.[41,45] Considering the variation in utility scores, various studies have sought to determine HSU values for cervical degenerative disease before and after ACDF.[42,50,51] Furthermore, Chotai et al. sought to find the best PROMs to convert to HSU, and concluded that SF-6D was the preferred measure to assess quality for cost-effective analyses evaluating cervical spine surgery.[52]

To compare the cost-effectiveness between two treatments or intervention, metrics developed include the cost-effective ratio (CER), defined as the cost per QALY, and the incremental cost-effective ratios (ICER), defined as the difference in cost divided by the difference in quality.[40,44,53–55] An ICER for the surgical intervention in question can then be compared to thresholds to consider whether it is cost-effective.[44,56] Current literature uses arbitrary cost thresholds for procedures that are considered cost-effective (represented in cost per QALY gained), with US ranges estimated at $50,000 to $100,000, and UK ranges stretching from $40,000 to $60,000.[47,56–59] Procedures below the lower bound are considered highly cost-effective and those above the upper bound are considered unfavorable.[47,56–59] However, it is important to note that these thresholds are arbitrary, outdated, and continue to be under significant debate.[60]

In addition, other costs to consider are direct and indirect costs.[41,44,61] Direct costs may include factors such as inpatient hospital stay, surgeon's fee, cost of readmission, and costs associated with events after discharge, such as how frequently patients visit healthcare providers, medication use, and use of diagnostic imaging.[41,44,61,62] These costs are typically gathered from payor and reimbursement data.[41,44,61,62] Indirect costs may include the amount of workdays that

are lost by either the patient or their caregiver, or a patient that may continue to work while having some type of disability leading to loss of productivity.[41,61]

Value of Care in Spine Surgery:

Currently, there continues to be significant debate regarding the preferred method for calculating value of treatments in spine surgery and the components that define value of care.[41,43,44,61,63–67] Ratliff and colleagues discuss the importance of choosing the appropriate metric for quality or utility scores and, more importantly, collecting these metrics at the appropriate time points.[40] However, given the diversity and complexity of spine pathology cases and interventions, a consensus to standardize quality metrics is difficult to reach.[40] The authors also describe the varying definitions for reporting quality, which can be dependent on what perspective is being considered—either the payor's or societal.[40,41] Furthermore, the varying perspectives and costs, such as hospital costs from the payor's perspective, loss of productivity from the social perspective, or varying reimbursements from different insurers, may further complicate methods of calculations to determine the most cost-effective intervention.[40,41]

Although previous studies have used healthcare utilization metrics, such as readmission, revision surgery, length of stay or complications, to determine cost-effectiveness, these metrics may not be the most appropriate for measuring value in care.[64] Instead, moving towards utilizing PROMs with more accurate cost exploration, such as a time-driven activity-based coding (TDABC) analysis, may allow spine surgeons to deliver better value-based care.[64]

Overall Trends and Costs of ACDF and CDA:

Several studies have demonstrated positive clinical outcomes after ACDF surgery, and this procedure is considered the gold standard treatment for various cervical degenerative diseases.[68–70] Nevertheless, recent studies have demonstrated an increased rate of CDA use for similar pathologies.[71–76] In a retrospective review of a nationwide inpatient sample, Nesterenko et al observed an estimated 700% increase in CDA cases performed from 2005 to 2008 (344 to 2434).[76] Additionally, Lu and colleagues reported an 11.8% increase in CDA procedures from 2008 to 2010, while Niedzielak et al noted that the compound annual growth rate (CAGR) of CDA from 2005 to 2014 was 20.5% for primary procedures and 5.84% for revision procedures.[71,74] More recently, Witiw et al reported an increase in the proportional utilization rate of CDA from 2009 to 2017 (5.6 to 28.8 per 100 ACDF cases), noting that the largest increase was after 2013, likely secondary to more devices being approved after this date.[75]

Cost comparisons between these two interventions has also changed over time. Liu and colleagues reported that there was an overall increase in cost, adjusting for inflation, from 2001 to 2013 in cervical spine surgery.[77] Directs costs for ACDF are estimated to be around $5,396 to $29,898 compared to estimated costs of $4,499 to $25,029 for CDA.[44,50,78] Using the Blue Health Intelligence national claims database, Radcliff and colleagues compared the total costs for the index procedure and for continuous monthly costs per patient in a four-year follow-up time period.[78] The authors reported that the mean costs for index procedures was significantly lower in CDA than ACDF ($22,761 compared to $25,029, respectively).[78] At 2 year follow-up, the authors reported that CDA continued to be significantly less compared to ACDF ($34,979 compared to $39,820, respectively).[78] When evaluating costs per patient per month of the two interventions, CDA was also found to be significantly less than ACDF at 1, 2, and 3 year follow-up.[78] Furthermore, Chotai et al also found increased costs associated with ACDF, with

preoperative anticoagulation, length of surgery, length of hospital stay, number of operative levels and postoperative imaging modality identified as independent predictors for increased cost in the 90 day postoperative period.[62] In contrast, a retrospective review of the National Inpatient Sample of the Healthcare Cost and Utilization project database, Nandyala and colleagues did not find a significant difference in total hospital costs between ACDF and CDA.[79]

Despite the increased rate in utilization reported in the above studies, in a survey of 383 AO Spine members, Chin-See-Chong and colleagues illustrated that ACDF continued to be the dominant treatment compared to CDA, with participants citing limited reports for cost-effectiveness and benefits as the most important reasons for reduced CDA adoption.[39] Similarly, Nunley et al noted insurance coverage and reimbursement as potential barriers for increased utilization of cervical arthroplasty.[2]

Comparison of cost-effectiveness between ACDF and CDA

Since the FDA approved cervical disc replacements in 2007, various studies have investigated the cost-effectiveness of these devices compared to ACDF. [47,78,80–87] In a CEA study comparing single-level CDA and ACDF utilizing Medicare charge and reimbursement data, Qureshi et al. reported that, assuming 20-year prosthesis survival, CDA was the more cost-effective surgical intervention over the lifetime of a patient with a CER of $3,042 compared to $8,760 per QALY for CDA and ACDF, respectively.[80] In addition, the authors reported that CDA was the more cost-effective intervention with an ICER of $2,394 per QALY.[80] However, when the authors used sensitivity analyses to incorporate device durability and a willingness-to-pay threshold (WTP) of $50,000, ACDF was found to be the more cost-effective intervention if the CDA failed before 9.75 years of use.[80] Yet, if the prosthesis survives for at least 11 years,

CDA may be the more cost-effective option.[80] Consistent with these findings, Ament and colleagues using a Markov model demonstrated that CDA was the more cost-effective treatment, with an ICER of $24,594 per QALY compared to ACDF at 2 year follow-up.[83] Similarly, at 5 year follow-up, Ament et al. found that CDA was the dominant intervention when taking direct costs into consideration with an ICER of $8,518 per QALY.[84] In comparison to the previous 2 year study, the large difference in the ICERs demonstrated that CDA continued to be cost-effective at 5 years using a WTP threshold of $50,000.[83,84] In a cost-effective analysis study also utilizing a Markov model with 5 year follow-up, McAnany et al reported a CER for CDA and ACDF as $35,976 and $42,618 per QALY, respectively.[81] The authors also noted an ICER of -$557,849 demonstrating that CDA was the dominant strategy in this model.[81] In a long-term follow-up study, McAnany et al reported that the 7-year cost for CDA was $172,989 compared to $143,714 for ACDF.[82] They reported CERs as $38,247 for CDA compared to $37,325 for ACDF per QALY.[82] Although the CERs of both treatments demonstrated cost-effectiveness, authors concluded that CDA was more favored when comparing treatments with an ICER of $43,522/QALY for CDA using a WTP of $50,000.[82] Similarly, Radcliff et al reported that CDA was more cost-effective than ACDF at 7 year follow-up utilizing Markov analysis and reporting net monetary benefit—an alternative to ICER.[87] Furthermore, the authors demonstrated that CDA had a net positive and mean NMB of $20,679 [$6,053,-$35,377] compared to ACDF, suggesting that the positive cost-effective benefits of CDA may be due to the small increase in QALYs and decrease in secondary surgical interventions.[87] Utilizing a Markov analysis, Kim et al. reported that the 7 year cost for CDA and ACDF was $105,332 and $103,911, respectively.[85] The authors also illustrated that the QALYs gained for ACDF and CDA was 5.16 [95CI: 3.08-7.24] and 5.33 [95CI: 3.21-7.45], respectively and reported an ICER of $8,111 per QALY

gained, favoring CDA as the more cost-effective strategy.[85] Overall results of these studies suggest that at 7-year follow-up, CDA continued to be a more cost-effective treatment strategy compared to ACDF.

In contrast to the aforementioned studies, other reports suggest ACDF may be more cost-effective and describe limitations with analyses of CDA expenditures. Overley and colleagues found the five year cost of CDA and ACDF to be $130,417 and $116,717, respectively.[86] Moreover, the authors reported that neither treatment was found to be dominant over the other in their model with CDA found to have an ICER of $62,337, above the WTP threshold of $50,000.[81] Warren et al illustrated that ACDF was more cost-effective than CDA in terms of cost per QALY whether using hospital or total costs, as well as using NDI or SF-36 as the utility measure.[88] For example, using hospital costs and SF-36, the authors reported cost per QALY at year 1 of ACDF and CDA as $70,034 and $106,690, respectively.[88] Additionally, the costs per QALY at year 2 was reported for ACDF compared to CDA as $34,272 and $50,011, respectively, demonstrating the potential cost-effective benefit of ACDF over time.[88] When calculating the ICER to compare treatments from either NDI or SF-36, the authors found both were cost-effective using the common WTP threshold of $50,000; however, these results may be limited by the study's two-year follow-up.[88] Additionally, Goz and colleagues reported potential limitations with utilizing a national database, such as the National Inpatient Sample, in studies that have demonstrated the cost-effectiveness of CDA.[28] Notably, the authors demonstrated that ACDF patients were found to be older and have more comorbidities compared to the CDA patients.[28] Furthermore, although CDA was reported to cost approximately $549 less than ACDF based on cost-to-charge ratios, the authors found that ACDF was in fact the less expensive option when adjusting for baseline differences, such as age or having multiple comorbidities.[28]

However, it is important to note that these results should be interpreted with caution as the use of ICD-9 codes may not always be accurate.[28]

Two-level interventions portray a different picture. In a cost-effective analysis of two-level CDA, Merrill et al reported the 7-year cost of CDA and ACDF as $176,654.19 and $158,373.48, respectively.[89] Additionally the authors demonstrated that the QALY gained was 4.56 for CDA and 4.44 for ACDF, with a net gain of 0.21 QALYs for CDA over 7 years.[89] Likewise, the cost-effectiveness ratio of CDA and ACDF were $37,99.53 per QALY and $35,653.72 per QALY, respectively, illustrating that both procedures are cost-effective when assuming a WTP of $50,000.[89] Nevertheless, when comparing an ICER of CDA of $89,021 per QALY to the WTP threshold of $50,000, the authors found that CDA was not necessarily the most cost-effective treatment despite a gain in QALY.[89]

Although there are limited reports using indirect costs from a societal perspective, Ghori et al. demonstrated that ACDF was more expensive in the long-term with costs of $31,780 compared to $24,119 for patients aged 45 to 65 years old, and taking into consideration loss of productivity and reoperation rates.[90,91] Ament et al. also demonstrated that CDA was the leading intervention with an ICER of -$165,103 per QALY when considering indirect costs and using $50,000 as the threshold for WTP at 5 year follow-up.[84] These results suggest that CDA is more cost-effective when considering decreased productivity loss and increased return-to-work compared to ACDF.[84]

Healthcare Utilization

Reoperation rates and healthcare utilization can be an alternative method to consider when assessing cost-effectiveness of a surgical intervention.[41,44] Rumalla and colleagues showed

that ACDF had a lower overall hospital cost compared to CDA, but cervical arthroplasty was associated with shorter length of stay, less complications, and adverse events during patient discharge disposition.[92] When comparing rates and costs of revision procedures after either cervical arthroplasty or ACDF, Nandyala and colleagues demonstrated that revision CDA procedures had a significantly greater associated hospital cost compared to revision ACDF ($16,998 compared to $15,222, respectively) with a revision rate of 2.0% for ACDF and 7.7% for CDA.[79] In addition, Saifi et al reported that the mean hospital cost was significantly greater for ACDF, but CDA was found to have a greater proportion of patients with a "mean revision burden"— measured as revision procedures divided by the sum of primary and revision procedures.[93] In contrast, Kumar et al reported that there was no significant difference in healthcare utilization between ACDF and CDA at 5 years when considering revisions and readmissions.[94] The differences in results may be attributed to the various patient sampling protocols from distinct national databases; nevertheless, components of healthcare utilization such as revision, readmission, and length of stay are important to consider as they may play a role in long-term costs that can affect future cost-effectiveness models.

Limitations of Cost-Effective Analysis Studies

Given the amount of cost-effective analyses used to compare surgical interventions, potential limitations should be considered when evaluating results including varying definitions for calculating cost and quality measures.[44,95] Although PROMs and HUS are continuously used to evaluate health-related quality of life, there continues to be a paucity in the literature of the most appropriate time points to collect these measures, which can ultimately affect resulting cost-analyses performed.[41,44,45,47] As future studies continue to assess the most appropriate

quality measure for evaluating spine surgery, standardization of metrics will be necessary for generalizability of findings. Furthermore, Markov analyses may have limitations as they are based off varying assumptions that are used in the model and only account for the current health state of a patient rather than for potential future health states.[91,96] Despite past long-term reports for cervical arthroplasty, there are currently limited studies with greater than 10-year follow-up, leading to gaps in knowledge of long-term reoperation and prosthesis survival rates that may impact cost-effectiveness analyses.[80,96]

Conclusion

Previous cost-effective studies have demonstrated that both ACDF and CDA are cost-effective procedures.[86,89] Moreover, several studies have demonstrated that CDA may be more cost-effective with 5- to 7-year follow-up.[80–85,87] Yet, ACDF surgery continues to be the more commonly used procedure.[71–73] Future studies are needed to demonstrate long-term follow-up on prosthesis survival and clinical outcomes to further elucidate the cost-effectiveness of cervical disc arthroplasty compared to ACDF, and determine if more widespread adoption is warranted.

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