

Total Disc Arthroplasty and Anterior Cervical Discectomy and Fusion in Cervical Spine: Competitive or Complimentary? Review of the Literature

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Abstract

Anterior cervical discectomy and arthrodesis has come to represent standard of care for patients with persistent radicular and/or myelopathic symptoms that have failed to improve with conservative treatments. One potential complication of the procedure is the accelerated degeneration of the vertebrae and the intervertebral discs adjacent to the level fused and the effects of fusion on those levels. The concern that fusion may be a contributing factor to accelerated adjacent segment degeneration led to increased interest in cervical disc replacement after anterior decompressive surgery. Several studies analyzing the short-term outcomes of the disc replacement procedure have been published since then, and the pros and cons of both procedures continue to remain a topic of debate among the scientific community. The analysis of published literature and our own experience has convinced us that the overall longer-term clinical outcomes after anterior cervical discectomy and fusion (ACDF) and total disc replacement (TDR) in the general patient population are not significantly different in terms of symptomatic improvement, neurological improvement, and restoration to better quality of life. Age of the patients and number of affected levels may impact the outcomes and hence determine the choice of optimum procedure. To definitely compare the incidence of adjacent segment disease after these procedures, multi-institutional studies with predetermined and unanimously agreed upon clinical and radiological criteria should be undertaken and the results analyzed in an unbiased fashion. Until that time, it is reasonable to assume that ACDF as well as cervical TDR are both safe and effective procedures that may have outcome benefits in specific patient subgroups based upon demographics and clinical/radiological parameters at the time of surgery.

Keywords

- ▶ cervical spine
- ▶ total disc arthroplasty
- ▶ ACDF

Smith and Robinson introduced anterior cervical discectomy and arthrodesis in 1958 as a surgical option for the management of cervical disc disorders.¹ Since then, the procedure has gained acceptance and has come to represent standard of care for patients with persistent radicular and/or myelopathic

symptoms that have failed to improve with conservative treatments.^{2,3} However, as longer-term results of the procedure became available, the outcome studies increasingly focused on the adverse effects of this procedure on the cervical spine.^{4,5} One of the areas specifically investigated

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was the vertebrae and the intervertebral discs adjacent to the level fused and the effects of fusion on those levels.⁶ The concern that spinal fusion may be a contributing factor to accelerated adjacent segment degeneration led to increased interest in “motion preservation” technology and popularity of cervical disc replacement in the reconstruction after anterior decompressive surgery. Several studies analyzing the short- and longer-term outcomes of the disc replacement procedure have been published since then.^{7–10} A review of published literature highlights several important clinical questions, the answers to which continue to elude the scientific community, namely:

1. Are the short- or long-term clinical outcomes better in patients with disc arthroplasty as compared with anterior cervical discectomy and fusion (ACDF)?
2. Is there a significant difference in the incidence of symptomatic adjacent segment degeneration after the two procedures?
3. Is there a strong, evidence-based rationale to perform total disc replacement (TDR) instead of ACDF?
4. Are there specific patient subsets in which either of the procedures may provide better longer-term outcomes (index level or adjacent segment disease [ASD])?

We hereby analyze the available data from the published literature and our personal experience and attempt to answer these four questions.

Primary Outcomes

The clinical success of ACDF continues to remain unchanged even at follow-up as long as 20 years. Bohlman et al² reported 67% of patients with no neck/arm pain 20 to 33 years after initial surgery at single or multiple levels. In their series, 88.5% of patients had no functional deficit after surgery compared with 45% with motor deficit and 63% with sensory deficit preoperatively. In addition, 80% of their patients were able to return to work after surgery and maintain socially and economically productive life. These results are “excellent” by all standards and continue to reaffirm the success of ACDF procedure.³

When we consider the primary outcomes after disc replacement surgery and attempt to compare them with outcomes for ACDF, the following differences confound the comparison: (1) the longest published follow-up period for TDR is ~8 years⁹; (2) most of the published data for TDR consist of patients with one-level^{11,12} or two-level^{10,13} disease; and (3) the data for TDR are usually gathered from the patients who have participated in the randomized controlled trials (RCT) for particular implants. Such trials have very stringent inclusion/exclusion criteria for selecting patients and are often criticized as not representing the general patient population.

Although such criticism is understandable, data from these trials are also the most unbiased and stringently analyzed and hence represent class I data. Most published results of the ACDF procedure are retrospective and/or anecdotal experi-

ence of a single surgeon or institution, thus qualifying as class III studies at best. Additionally, the instruments and success criteria used for the ACDF studies have varied according to the different authors' judgment.

Making a true comparison of the outcomes after the two procedures therefore presents pragmatic challenges that are often overlooked during debates in scientific meetings. Nevertheless, published data from the RCTs for total disc replacements have shown a comparable success rates for both procedures at the average follow-up of 2 to 4 years.^{12,14} These publications, though, clearly establish the noninferiority of the total disc replacement procedure to the ACDF; they also tend to question the rationale for utilizing TDR as an alternative to the fusion procedure. Skeptics of the TDR procedure have pointed out the lack of benefit of TDR procedure over ACDF¹⁵ and have questioned the validity of performing TDR as an alternative to ACDF for similar indications. Our institution has been involved in total disc replacement clinical trials since 2004 and has investigated three different cervical artificial discs for one- and two-level disease. Our own experience indicates that total disc arthroplasty provides a significantly quicker improvement in the clinical and functional status. The visual analogue scale (VAS) pain scores and neck disability index (NDI) scores for the patients at 6 weeks and 3 months after TDR were significantly lower than those after ACDF. This translated to reduced use of narcotic analgesics and quicker return to full employment.¹⁶ The success rate for ACDF, however, tends to catch up with that for TDR as time elapses so that at 1 and 2 years' follow-up, the success rates are comparable for the two procedures. These results have been independently confirmed by Coric et al¹² in their data set that analyzed 269 patients with single-level disease.

More recently, we combined the data from three collaborating institutions of 271 patients who had participated in four different TDR device trials for one and/or two-level disease in an attempt to identify subgroups of patients who may have additional benefit from either TDR or ACDF.¹⁷ We analyzed the VAS and NDI scores from these patients and reviewed results of complete neurological examination at 1 to 6 years' follow-up. We found that longer-term clinical outcomes after TDR are significantly better than ACDF for two-level cervical radiculopathy in patients 50 years or older (►Tables 1, 2 and ►Fig. 1). The outcomes were comparable for single-level disease. The results were surprising because TDR has conventionally been supported for younger patients with single-level disease and the prevalent belief has been that the outcomes would not differ significantly in older age groups.

Adjacent Segment Disease

The problem of symptomatic ASD after anterior cervical surgery was first studied in detail by Hilibrand et al.⁶ They assessed symptomatic patients based upon plain radiographs and magnetic resonance imaging of the cervical spine and classified patients into four different categories according to the symptoms and evidence of adjacent segment degeneration. In their positional work, they established that

Table 1 Clinical Outcome Table for Two-Level Surgery in Patients 50 Years or Older Showing a Difference in Success Rates

	TDR	ACDF	p Value
Overall success (%)	84	69	0.013 ^a
VAS improvement (mm)	58	46	0.013 ^a
NDI improvement (%)	45	32	0.027 ^a
ASD (%)	0	2	NS

TDR, total disc replacement; ACDF, anterior cervical discectomy and fusion; VAS, visual analogue scale; NDI, neck disability index; ASD, adjacent segment disease; NS, not significant.

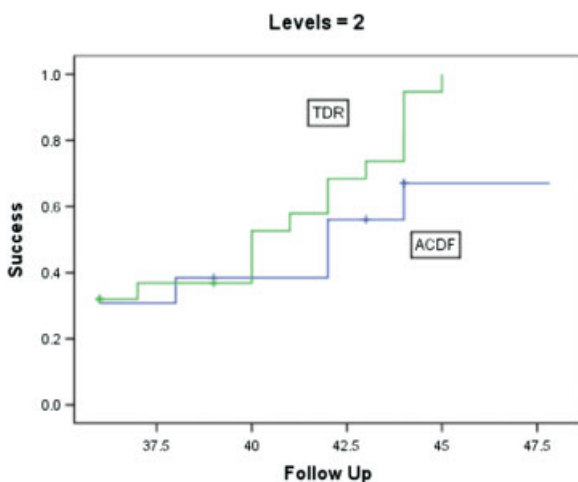
^ap value significant < 0.05.

Table 2 Clinical Outcome Table for Single-Level Surgery in Patients < 50 Years Showing No Difference in Success Rates

	TDR	ACDF	p Value
Overall success (%)	80	80	0.9
VAS improvement (mm)	61	55	0.64
NDI improvement (%)	41	47	0.53
ASD (%)	2	3.7	0.24

TDR, total disc replacement; ACDF, anterior cervical discectomy and fusion; VAS, visual analogue scale; NDI, neck disability index; ASD, adjacent segment disease.

symptomatic ASD occurred in a fourth of the patient population within the first 10 years after ACDF. Wigfield et al¹⁸ in their bench study showed that an artificial disc in the cervical spine resulted in reduced stresses in the annulus of the neighboring segments compared with the spines with a simulated fusion. This led to the formulation of the theory that restriction of physiological motion at the fused segments causes predisposition to degeneration at the adjacent levels due to increased mechanical stresses.¹⁹ Hilibrand et al in a follow-up study to their original work admitted that the

**Figure 1** Survival curves (Kaplan-Meier) for clinical success after two-level anterior cervical surgery in patients > 50 years comparing total disc replacement (TDR) to anterior cervical discectomy and fusion (ACDF).

scientific literature was unclear whether the ASD was a result of the spinal fusion with iatrogenic motion restriction or whether it represented a progression of the natural history of degeneration.²⁰ Nevertheless, the strong conviction in the scientific community that reduced motion at the index level after fusion contributed to the development of adjacent segment degeneration continued to be prevalent. The clinical proof for this dictum has not been established in any published study. There are two possible reasons for the lack of literature. First, most of the published studies were done as RCTs assessing the safety and efficacy of the cervical disc replacement procedure. The primary end points in such trials are focused on improvements in patient's symptoms attributable to the index level. Second, the published results are mostly focused on the outcomes at 24-month follow-up, a period too short to assess ASD.

We attempted to study the incidence of documented adjacent segment degeneration after cervical total disc arthroplasty and assessed the projected ASD-free survival rates in 93 patients receiving total disc arthroplasty for cervical degenerative disc disease with one- and two-level cervical degenerative disc disease treated with total disc arthroplasty or ACDF as a part of three different RCTs.²¹ In our analysis, the clinical evidence failed to corroborate the widely professed theory that total disc arthroplasty could potentially reduce the risk of developing ASD in the patients. Considering that the number of patients was relatively small and the follow-up period of 36 months might be insufficient to analyze ASD, we further expanded our analysis to examine the incidence of ASD at 48-month follow-up in 170 patients with one- and two-level cervical disease who received either TDR or ACDF in three different RCTs at two investigating institutions.²² There was no significant difference in the incidence of ASD in the two groups ($p = 0.24$). The mean period of freedom from ASD was 46.04 ± 0.6 months after ACDF and 48.7 ± 1.04 months after total disc arthroplasty. Because both these periods were within one standard deviation of the 95% confidence interval for the ASD-free survival, no statistical significance could be established for the type of procedure (fusion versus disc arthroplasty) influencing freedom from ASD. Coric et al¹² state that at the 24-month follow-up, there was significantly more severe adjacent-level deterioration evident in the ACDF group than in the TDR group but their results can be easily explained by the following arguments: first, their analysis was purely radiographic and was based upon interpretation of plain radiographs regardless of the clinical assessment of the patients, and second, no magnetic resonance images were obtained for assessing the ASD and hence the disease was not assessed according to the Hilibrand criteria. In absence of clinical correlation and magnetic resonance imaging, in our opinion, it is not relevant to adjudicate the superiority of the TDR procedure over ACDF based on ASD alone. Similar attempt was made by Garrido et al.²³ Again, their analysis was purely based on plain radiographic images without consideration of the patients' clinical signs and symptoms. Kelly et al,²⁴ on the other hand, reported that at 24-month follow-up from 199 patients, no significant difference in adjacent segment range of motion (ROM) was observed between ACDF and total disc arthroplasty.

Only time was a significant predictor of postoperative ROM at both the cranial and caudad levels.

Discussion

The analysis of published literature and our own experience has convinced us that the overall longer-term clinical outcomes after ACDF and TDR in the general patient population are not significantly different in terms of symptomatic improvement, neurological improvement, and restoration to better quality of life. Total disc arthroplasty, however, definitely affords a quicker recovery that may translate to an overall reduced consumption of narcotic pain medication and quicker return to work. Patient age and single- versus two-level disease may both affect the outcomes and hence determine the choice of optimum procedure. Preliminary data indicated that total disc replacement may provide better outcomes for two-level disease, although larger populations may need to be studied for a prolonged follow-up to statistically establish this theory.

To definitely assess the incidence of ASD, standard criteria should unanimously be agreed upon. In our opinion, just radiographic analysis without taking into account the clinical picture of the patient cannot be judged as sufficient to assess ASD. Additionally in this age of sophisticated imaging technology, plain radiographs should definitely be supplemented with computed tomography and/or magnetic resonance imaging to study the radiographic degeneration process at the adjacent segments. Hilibrand's criteria, as established more than a decade ago, still continue to be the most universally accepted and clinically relevant for establishing the ASD and are invaluable for any unbiased analysis involving ASD.

Disclosures

Ajay Jawahar, None
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