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Cervical artificial disc replacement versus fusion in the cervical spine: a systematic review comparing multilevel versus single-level surgery

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ABSTRACT

Study design: Systematic review.

Clinical questions: What is the effectiveness of multilevel cervical artificial disc replacement (C-ADR) compared with multilevel fusion with respect to pain and functional outcomes, and are the two procedures comparable in terms of safety? What is the effectiveness of multilevel C-ADR compared with single-level C-ADR with respect to pain and functional outcomes, and are the two procedures comparable in terms of safety?

Methods: A systematic review was undertaken for articles published up to October 2011. Electronic databases and reference lists of key articles were searched to identify studies comparing multilevel C-ADR with multilevel anterior cervical discectomy and fusion (ACDF) or comparing multilevel C-ADR with single-level C-ADR. Studies which compared these procedures in the lumbar or thoracic spine or that reported alignment outcomes only were excluded. Two independent reviewers assessed the strength of evidence using the GRADE criteria and disagreements were resolved by consensus.

Results: Two studies compared multilevel C-ADR with multilevel ACDF. While both reported improved Neck Disability Index (NDI) and Short-Form 36 (SF-36) scores after C-ADR compared with ACDF, only one study reported statistically significant results. Seven studies compared single-level C-ADR with multilevel C-ADR. Results were similar in terms of overall success, NDI and SF-36 scores, and patient satisfaction. There is discrepant information regarding rates of heterotopic ossification; dysphagia rate may be higher in multilevel C-ADR.

Conclusions: The literature suggests that outcomes are at least similar for multilevel C-ADR and ACDF and may favor C-ADR. Future studies are necessary before firm recommendations can be made favoring one treatment strategy. Multilevel C-ADR seems to have similar results to single-level C-ADR but may have higher rates of heterotopic ossification and dysphagia.

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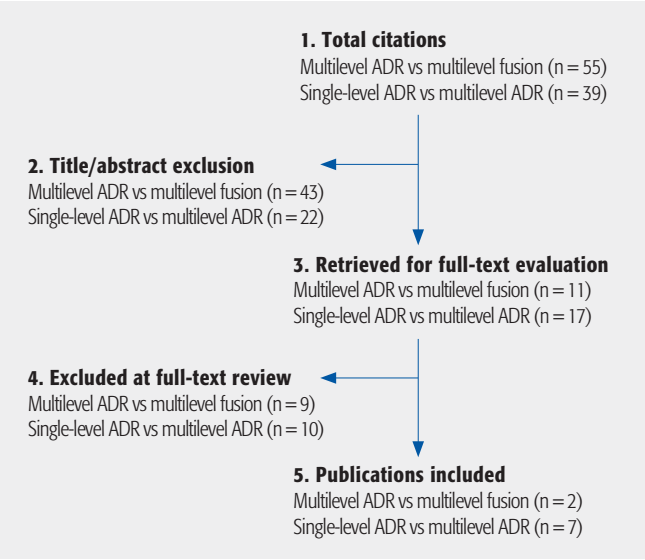
STUDY RATIONALE AND CONTEXT

While the benefit of single-level C-ADR is increasingly well-described in the literature, the role of multilevel C-ADR is less clear. The purpose of this systematic review was to compare outcomes after multilevel C-ADR with those after multilevel ACDF and to evaluate whether favorable single-level C-ADR outcomes extend to multilevel surgery.

CLINICAL QUESTIONS

1. What is the effectiveness of multilevel C-ADR compared with multilevel fusion with respect to pain and functional outcomes?
2. What is the safety of multilevel C-ADR compared with multilevel fusion?
3. What is the effectiveness of multilevel C-ADR compared with single-level C-ADR with respect to pain and functional outcomes?
4. What is the safety of multilevel C-ADR compared with single-level C-ADR?

Fig 1 Results of literature search.



MATERIALS AND METHODS

Study design: Systematic review.

Sampling:
Search: PubMed, Cochrane collaboration database, and National Guideline Clearinghouse databases; bibliographies of key articles.
Dates searched: January 1980–October 1, 2011.

Inclusion criteria: Studies comparing (1) multilevel C-ADR with multilevel fusion in the cervical spine; (2) multilevel C-ADR with single-level C-ADR in the cervical spine; and (3) studies published in English-language peer-reviewed journals.

Exclusion criteria: (1) Studies in the thoracic or lumbar spine; (2) disc nucleus replacement, annular reconstruction techniques, or other forms of intradiscal spacers as comparators; (3) studies reporting alignment outcomes only; and (4) case-reports.

Outcomes: Neck Disability Index (NDI), pain in the neck and arm (Visual Analog Scale [VAS]), Odom's criteria (overall success), neurological success, Quality of Life (SF-36 Physical Component Score [PCS] and Mental Component Score [MCS]), adjacent segment disease (ASD), range of motion (ROM), return to work, analgesic use, subsequent surgeries, and complications/adverse events. Odom's criteria classifies patients according to the following categories: (1) excellent—all preoperative symptoms relieved; abnormal findings improved; (2) good—minimal persistence of preoperative symptoms; abnormal findings unchanged or improved; (3) fair— definite relief of some preoperative symptoms; other symptoms unchanged or slightly improved; and (4) poor— symptoms and signs unchanged or exacerbated. NDI asks patients to evaluate severity of symptoms and disability in the following ten areas: pain intensity, personal care, lifting, reading, headache, concentration, work, driving, sleeping, and recreation.

Analysis: Descriptive statistics.
Details about methods can be found in the Web Appendix at *www.aospine.org/ebsj*

RESULTS

A total of nine studies were found that met the inclusion criteria (**Fig 1**). Of the nine, two, a randomized controlled trial (RCT) and a prospective cohort, compared C-ADR with ACDF; and seven, four prospective and three retrospective cohorts, compared multilevel C-ADR with single-level C-ADR in the cervical spine. Further details on the class of evidence rating for these studies can be found in the *Web Appendix at www.aospine.org/ebsj*, but the current level of evidence available on the topic is relatively low. Demographic and study details are provided in **Table 1**.

Multilevel C-ADR versus multilevel ACDF

Overall success

- Odom's criteria was reported by one study at 2 years with excellent or good results seen in 96.7% of multilevel C-ADR patients compared with 84.4% of multilevel ACDF patients (P = not reported) [1].

Function and pain (*Table 2*)

- One study reported outcomes at 1 year and found that multilevel C-ADR resulted in greater improvement from baseline compared with multilevel ACDF in NDI (76.0% vs 64.7%, P = .03) and VAS neck pain (74.0% vs 64.8%, P = NR) and; conversely, slightly less improvement was seen for VAS arm pain: 74.6% vs 80.6% (P = NR) [1].
- Both studies reported greater improvement from baseline to 2 years in NDI and VAS neck pain following multilevel C-ADR vs multilevel ACDF [1, 2]; however, only one study [1] reported that the differences were statistically significant, respectively: NDI, 78.0% vs 62.7% (P = .02) and 70.5% vs 69.5% (P = ns); VAS neck pain, 79.5% vs 63.4 (P = .01) and 62.5% vs 58.0% (P = not significant).

Quality of life

- In one study, both the C-ADR and ACDF groups improved from their baseline SF-36 PCS of 35 and 34, respectively, to 49 and 46 at 1 year and 50 and 45 at 2 years; however, the C-ADR group showed a statistically greater percentage improvement at both time points over baseline compared with the ACDF group: 40.0% vs 35.3% (P = .03) and 42.9% vs 32.4% (P = .01) [1].

Complications

- Only one study reported complications following surgery [1]. One incidence of deep vein thrombosis was seen in the C-ADR group and one case of dysphagia in the ACDF group.
- There were no occurrences of cerebrospinal fluid leak or hematoma in either group and no incidences of vascular or neurological complications, spontaneous fusions, device failure, or explantations in the C-ADR group.

Single-level versus multilevel C-ADR

Overall and neurological success

- Odom's criteria was reported by two studies, both of which reported similar proportions of excellent or good results between the single-level and multilevel C-ADR groups, respectively: at 4 years (88.8% [71/80] and 88.9% [8/9]) and 6 years (90.6% [48/53]) vs 100% (6/6)] in one study, and at 3 years 76% (54/71) and 85% (59/69)] in the second study [3, 4].
- One study defined overall success as an improvement of ≥15% in NDI and absence of revision surgery; rates at 2 years were similar between the single-level (69%) and multilevel (66%) groups (follow-up numerators and denominators not reported) [5].
- Overall neurological success was reported by one study which stated that single-level and multilevel C-ADR patients showed similar rates at 1 and 2 years, 4 years, and 6 years follow-up (no other data presented) [3].

Function and pain (*Table 3*)

- No significant differences were seen between single-level and multilevel C-ADR in NDI or VAS neck pain scores at 1, 2 or 3 years follow-up as reported by three studies [2, 4, 6,].
- One study conducted follow-up at 4 and 6 years and reported similar NDI scores between the groups at both periods (data NR); VAS arm and neck pain scores were lower in the multilevel compared with single-level C-ADR group (data NR) [3].
- Analgesic use at 2 years was compared between groups in one study with 32% of single-level patients compared with 53% of multilevel patients still using an analgesic (P = .03) [5]. This study did not define whether analgesic use referred to narcotic use only or whether it referred to use of both narcotic and non-narcotic analgesics.
- One study reported a Treatment Intensity Score which takes into account analgesic medication requirements and found that overall mean improvement from baseline was 39.3% vs 54.3% in single-level and multilevel C-ADR groups, respectively (P = NR) [4]. This study similarly did not define whether the Treatment Intensity Score considered narcotic use only or whether use of both narcotic and non-narcotic analgesics were considered.

Quality of life (*Table 4*)

- No significant differences were reported between single-level and multilevel C-ADR in SF-36 PCS and MCS at 1, 2, 4, or 6 years follow-up in two studies [3, 5].

Table 1 Characteristics of included studies.*

Author (year)/ study design	CoE	Demographics	Diagnosis	Interventions	Follow-up	Funding
Studies comparing multilevel C-ADR and multilevel ACDF						
Cheng et al [1] (2009) RCT Single site	II	C-ADR – N = 31 – Male %: 52 – Mean age: 45 y ACDF – N = 34 – Male: 50% – Mean age: 47 y	Spondylotic myelopathy or cervical radiculopathy due to a disc herniation or stenosis	C-ADR using the Bryan disc; all procedures performed by same surgeon ACDF with iliac crest autograft; anterior cervical plating with the Orion Cervical Plate System	2 y C-ADR: 96.8% (30/31) ACDF: 94.1% (32/34)	NR
Kim et al [6] (2009) Prospective cohort	III	C-ADR† – N = 12 – Male: 67% – Mean age: 46.9 (30–58) y ACDF† – N = 28 – Male: 61% – Mean age: 52.7 (30–78) y	Symptomatic single- or 2-level cervical disc disease Radiculopathy – C-ADR: 83% (10/12) – ACDF: 86% (24/28) Myelopathy – C-ADR: 17% (2/10) – ACDF: 14% (4/28)	C-ADR using Bryan disc ACDF with autogenous bone using various types of anterior cervical plates (ABC, Atlantis) or stand-alone cages (Blackstone, Solis)	C-ADR – Mean 18 (13–37) mo – % Followed up NR ACDF – Mean 21 (14–38) mo – % Followed-up NR	NR
Studies comparing single-level C-ADR and multilevel C-ADR						
Coric et al [7] (2010) Prospective cohort‡	II	N = 57 Male: 41.5% Mean age: 46.6 y	Symptomatic cervical radiculopathy or myelopathy	C-ADR	Follow-up: 2 y (93%; n = 53/57)	Primary author is a consultant for Depuy Spine and Spinal Motion
Goffin et al [3] (2010)§ Retrospective cohort	III	N = 98 Single level, n = 89 – Male: 42.7% – Mean age (± SD): 43.2 ± 9.0 y Multilevel, n = 9 – Male: 77.8% – Mean age (± SD): 49.3 ± 7.2 y	Radiculopathy due to: Disc herniation – Single level: 56.2% – Multilevel: 0% Spondylosis – Single level: 20.2% – Multilevel: 88.9% Both – Single level: 15.7% – Multilevel: 0% Myelopathy due to: Disc herniation – Single level: 5.6% – Multilevel: 0% Spondylosis – Single level: 2.2% – Multilevel: 11.1	C-ADR with Bryan disc	Follow-up: 4–6 y – 4 y: 100% – 6 y: 60.2% (59/98) Single level: 59.6% (53/89) Multilevel: 66.7% (6/9)	Research support and editorial assistance for this study was received from Medtronic Sofamor Danek. In addition, statistical analysis was conducted in collaboration with Medtronic. A nonstudy-related institutional grant for research and education was also received from Medtronic. Dr Lipscomb serves as a consultant for and owns stock in Medtronic.
Huppert et al [5] (2011) Prospective cohort	III	N = 231‖ Single level, n = 175 – Male: 40.0% – Mean age (range): 43.8 (23–63) y Multilevel, n = 56 – Male: 39.3% – Mean age (range): 48.2 - (34–65) y	DDD causing radiculopathy and/or myelopathy	Mobi-C C-ADR Single-level and multilevel procedures performed by same surgeons, using same operative procedure, during the same time interval No. of levels treated in multilevel group: – 2-level, n = 51; – 3-level, n = 4; – 4-level, n = 1	Single level: Mean 2.1 (1.5–2.6) y % Followed-up NR Multilevel: – Mean 2.0 (1.4–2.5) y – % Followed-up NR	NR

Table 1 (cont.) Characteristics of included studies.*

Author (year)/ study design	CoE	Demographics	Diagnosis	Interventions	Follow-up	Funding
Kim et al [2] (2009) Retrospective cohort	III	N = 52 Male: 55.8% Mean age (range): 47.2 (28–77) y Single level: n = 36 (69%) Multilevel: n = 16 (31%)	Herniated disc: 44.2% Spondylosis: 34.6% Mixed: 15.8% OPLL: 5.8%	Bryan C-ADR Concomitantly performed surgeries included: – interbody fusion (13.5%); – anterior microforami-notomy (15.4%)	Follow-up: mean 2.4 (1.5–3) y % Followed-up NR	NR
Kim et al [6] (2009) Prospective cohort	III	N = 51¶ Single level, n = 39 Male: 53.8% Mean age (range): 43.6 (24–74) y Multilevel, n = 12 – Male: 66.7% – Mean age (range): 46.9 (30–58) y	Radiculopathy Single level: 92.3% Multilevel: 83.3% Myelopathy Single level: 7.7% Multilevel: 16.7%	Bryan C-ADR All procedures performed by same surgeon	Follow-up: mean 1.5 (1.1–3.3) y % Followed-up NR	NR
Pimenta et al [4] (2007) Prospective cohort	II	N = 140 Single level, n = 71 – Male: 39.4% – Mean age (range): 45.5 (28–77) y Multilevel, n = 69 – Male: 40.6% – Mean age (range): 46.6 (29–80) y	HNP – Single level: 32.4% – Multilevel: 42.0% Spondylosis – Single level: 67.6% – Multilevel: 58.0% Radiculopathy – Single level: 73.2% – Multilevel: 66.7% Myelopathy – Single level: 26.8% – Multilevel: 33.3%	C-ADR using the PCM Porous Coated Motion Device Intervertebral Dynamic Disc Spacer No. of levels treated in multilevel group: – 2-level, n = 53 – 3-level, n = 12 – 4-level, n = 4	Follow-up: mean 2.2 (1–3.5) y Follow-up 100%	Corporate/ industry and foundation funds were received in support of this work. One or more of the author(s) has/have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article.
Tu et al [8] (2011) Retrospective cohort	III	N = 36 Male: 58.3% Mean age (range): 46.6 (29–60) y Singlelevel, n = 20 (55.6%) Multilevel, n = 16 (44.4%)	Disc herniation: 61.1% Spondylosis: 38.9% Radiculopathy: 50.0% Myelopathy: 13.9% Both: 19.4% Axial neck pain: 16.7%	C-ADR using Bryan	Follow-up: mean 1.6 (range, 1–2.3) y 1 y: 100% 2 y : 69.4% (25/36)	This study was supported by grant VGH 99-S6-001 from Taipei Veterans General Hospital. The authors report no conflict of interest.

* C-ADR indicates cervical artificial disc replacement; ACDF, anterior cervical discectomy and fusion; FSU, functional spinal unit; CoE, level of evidence; NR, not reported; RCT, randomized control trial; DDD, degenerative disc disease; OPLL, ossification of the posterior longitudinal ligament; HNP, herniated nucleus pulposis.

† The study reported comparisons between both single-level and multilevel C-ADR and ACDF. Only 2-level cases are reported for the purpose of this article.

‡ This study compared pooled groups of patients from three RCTs who underwent C-ADR vs ACDF (N = 98). Only the C-ADR group is reported here. Demographics are after loss to follow-up (n = 53).

§ Long-term follow-up results from Goffin et al [3]. The 98 patients included in this study agreed to participate in follow-up studies for up to 10 years; the original study had a total of 146 patients enrolled.

‖ A total of 384 patients were enrolled in this study; a total of 231 (60.2%) have completed their 2-month follow-up evaluation and were included in the analysis.

¶ Only the comparison between single-level and multilevel C-ADR is reported.

Table 2 Function and neck pain following multi-level C-ADR and multilevel ACDF.*

	NDI Mean score (% change from preop)			VAS neck pain Mean score (% change from preop)		
	C-ADR	ACDF	*P*	C-ADR	ACDF	*P*
Preop						
Cheng et al [1] (2009)	50	51	NS	7.3	7.1	NS
Kim et al [2] (2009)	26.4	26.2	NS	8.8	8.1	NR
1 year						
Cheng et al [1] (2009)	12 (76.0)	18 (64.7)	.03	1.9 (74.0)	2.5 (64.8)	NR
2 years						
Cheng et al [1] (2009)	11 (78.0)	19 (62.7)	.02	1.5 (79.5)	2.6 (63.4)	.01
Kim et al [2] (2009)	7.8 (70.5)	8.0 (69.5)	NS	3.3 (62.5)	3.4 (58.0)	NS

* C-ADR indicates cervical artificial disc replacement; ACDF, anterior cervical discectomy and fusion; NDI, Neck Disability Index; VAS, Visual Analog Scale; preop, preoperative; NR, not reported; and NS, not statistically significant.

Table 3 Function and neck pain following single-level and multilevel C-ADR.*

	NDI Mean score (% change from preop)			VAS neck pain Mean score (% change from preop)		
	Single	Multi	*P*	Single	Multi	*P*
Preop						
Huppert et al [5] (2011)	51.5	51.4	NS	5.3†	5.1†	NS
Kim et al [6] (2009)	25.3	26.4	NS	8.3	8.8	NS
Pimenta et al [4] (2007)	48	44	NS	8.6	8.5	NS
1 year						
Huppert et al [5] (2011)	25.5 (50.5)	30.0 (41.6)	NR	2.1 (60.4)	2.2 (56.8)	NR
Kim et al [6] (2009)	7.6 (69.9)	7.8 (70.5)	NS	3.7 (55.4)	3.3 (62.5)	NS
Pimenta et al [4] (2007)	27 (43.8)	20 (54.5)	NR	3.3 (61.6)	3.0 (64.7)	NR
2 years						
Huppert et al [5] (2011)	27.3 (47.0)	29.2 (43.2)	NS	2.4 (54.7)	2.4 (52.9)	NS
Pimenta et al [4] (2007)	26 (45.8)	22 (50.0)	NR	3.0 (70.0)	2.7 (68.2)	NR
3 years						
Pimenta et al [4] (2007)	21 (56.3)	11 (75.0)	NR	4.0 (53.5)	1.5 (82.4)	NR

* C-ADR indicates cervical artificial disc replacement; NDI, Neck Disability Index; VAS, Visual Analog Scale; preop, preoperative; NR, not reported; and NS, not statistically significant.
† Pain scores from Huppert et al [5] were normalized from a VAS 100 mm scale to a VAS 10 mm scale for comparison purposes.

Table 4 Health-related quality of life following single-level and multilevel C-ADR.*

Study/ follow-up	SF-36 PCS Mean score (% change from preop)			SF-36 MCS Mean score (% change from preop)		
	Single	Multi	*P*	Single	Multi	*P*
Preop						
Goffin et al [3] (2010)†	36.1	37.4	NS	40.1	35.5	NS
Huppert et al [5] (2011)	36.6	36.6	NS	35.3	34.3	NS
1 year						
Goffin et al [3] (2010)†	46.9 (29.9)	47.0 (25.7)	NR	50.0 (24.7)	46.1 (29.9)	NR
Huppert et al [5] (2011)	47.2 (29.0)	45.7 (24.9)	NR	45.9 (30.0)	44.0 (28.3)	NR
2 years						
Goffin et al [3] (2010)‡	45 (24.7)	49 (31.0)	NR	51 (27.2)	53 (49.3)	NR
Huppert et al [5] (2011)	46.7 (27.6)	43.9 (19.9)	NS	46.0 (30.3)	45.6 (32.9)	NS
4 years						
Goffin et al [3] (2010)‡	47 (30.2)	52 (39.0)	NR	52 (29.7)	52 (46.5)	NR
6 years						
Goffin et al [3] (2010)‡	47 (30.2)	51 (36.4)	NR	52 (29.7)	47 (32.4)	NR

* C-ADR indicates cervical artificial disc replacement; SF-36, Short-Form 36; PCS, Physical Component Score; MCS, Mental Component Score; preop, preoperative; NS, not statistically significant; and NR, not reported.
† Preoperative and 1 year scores were taken from Goffin et al [3] which reported short-term follow-up outcomes for the same population.
‡ Means estimated from figures provided in the article.

Table 5 Complications and adverse events following single-level and multilevel C-ADR.*

	Single level, % (n/N)	Multi-level, % (n/N)	*P*	Follow-up, y
Reoperation				
Coric et al [7] (2010)	5.0 (2/40)	16.7 (2/12)	NR	2
Huppert et al [5] (2011)	2.3 (4/175)	3.6 (2/56)	NS	2
Pimenta et al [4] (2007)	4.2 (3/71)	2.9 (2/69)	NS	NR
Revision				
Huppert et al [5] (2011)	0.6 (1/175)	0 (0/56)	NS	2
Heterotopic ossification				
Any				
Huppert et al [5] (2011)	66.7 (110/165)	55.0 (61/111)	.02	2
Tu et al [8] (2011)	30.0 (6/20)	75.0 (12/16)	.007	1
Grade IV				
Coric et al [7] (2010)	0 (40)	8.3 (1/12)	NR	2
Huppert et al [5] (2011)	10.3 (17/165)	7.2 (8/111)	NS	2
Pimenta et al [4] (2007)	1.4 (1/71)	0 (0/69)	NR	NR
Dysphagia				
Huppert et al [5] (2011)	4.0 (7/175)	16.1 (9/56)	.002	2
Device subsidence				
Huppert et al [5] (2011)	1.1 (2/175)	0 (5/56)	NS	2
Device migration				
Huppert et al [5] (2011)	0.6 (1/175)	1.8 (1/56)	NS	2
Infection				
Pimenta et al [4] (2007)	0 (0/71)	0 (0/69)	–	NR
Mortality				
Pimenta et al [4] (2007)	0 (0/71)	0 (0/69)	–	NR
Any event				
Goffin et al [3] (2010)	66.3 (61/92)	40.0 (4/10)	NR	6 †

* Incidences reflect the number of patients with one or more adverse event/complication. C-ADR indicates cervical artificial disc replacement; NR, not reported; and NS, not significant.
† Approximately 60% of all reported adverse events occurred 2 years after index surgery and about 15% of these events were continuations of earlier reports.

Patient satisfaction and return to work

- One study reported that 94.2% and 94.5% of patients who underwent single-level and multilevel C-ADR, respectively, would undergo the same procedure again [5].
- This same study reported that at 2 years 70% of single-level C-ADR patients and 46% of multilevel C-ADR patients had returned to part-time or full-time work ($P = .09$) with respective mean time-to-return-to-work of 4.8 vs 7.5 months ($P = .08$).

Complications (*Table 5*)

- Reoperation was reported by three studies, one of which reported a lower rate at 2 years following single-level compared with multilevel C-ADR, 5.0% vs 16.7% ($P = .22$) [7]. The remaining two studies reported similar reoperation rates between the groups, 2.3% vs 3.6% and 4.2% and 2.9%, respectively [4, 5].
- Two studies compared the rates of any grade of heterotopic ossification (HO) between groups. One study [5] reported a significantly higher rate of HO at 2 years among single-level patients, 66.7% vs 55.0% following multilevel C-ADR ($P = .02$). Conversely, the second study [8] reported a much lower rate at 1 year in those who underwent single-level C-ADR compared with multilevel, 30% vs 75% ($P = .007$).
- A significantly lower incidence of dysphagia was reported following single-level compared with multilevel C-ADR at 2 years in one study [5], 4.0% vs 16.1% ($P = .002$).
- Rates of revision, device subsidence or migration, infection, mortality, and other complications were similar between groups.

EVIDENCE SUMMARY

Table 6 Multilevel C-ADR versus multilevel ACDF

Pain and disability		
Outcomes	**Strength of evidence**	**Conclusions/comments**
1. Overall success	Very low **Low** Moderate High	Odom's criteria reported by one RCT at 2 years with excellent or good results seen in a greater proportion of multilevel C-ADR patients compared with multilevel ACDF patients.
2. VAS – Neck pain	**Very low** Low Moderate High	Greater improvement in neck pain from baseline to 1 and 2 years reported by two studies following multilevel C-ADR versus multilevel ACDF; however, only one reported that the differences were statistically significant.
–Arm pain	**Very low** Low Moderate High	Slightly greater improvement in arm pain at 1 year after multilevel C-ADR compared with multilevel ACDF in one study.
3. NDI	**Very low** Low Moderate High	Greater improvement from baseline to 1 and 2 years follow-up following multilevel C-ADR versus multilevel ACDF reported by two studies; however, only one reported that the differences were statistically significant.
4. Quality of Life	Very low **Low** Moderate High	The C-ADR group showed a statistically greater percentage improvement at 1 and 2 years over baseline compared with the ACDF group as reported by one RCT.
Complications		
Outcomes	**Strength of evidence**	**Conclusions/comments**
1. Overall complications	**Very low** Low Moderate High	Only one study reported complications following surgery with no differences reported between groups.

Table 7 Single-level versus multilevel C-ADR

Pain and disability		
Outcomes	**Strength of evidence**	**Conclusions/comments**
1. Overall success	Very low **Low** Moderate High	Three studies reported various measures of overall success (Odom's criteria, neurological success, composite measure) and found no statistical differences between treatment groups across 1 to 6 years of follow-up.
1. Pain	**Very low** Low Moderate High	Measured a variety of ways (VAS, analgesic use, treatment intensity score) across four studies. Inconsistent results regarding the effectiveness of one surgery to provide better pain relief over the other.
3. NDI	Very low **Low** Moderate High	No significant differences between single-level and multilevel C-ADR in NDI scores over 1 to 6 years follow-up as reported by four studies.
4. Quality of Life (SF-36 PCS and MCS)	**Very low** Low Moderate High	No significant differences were reported between single-level and multilevel C-ADR at 1, 2, 4, or 6 years follow-up in two studies.
5. Patient satisfaction	**Very low** Low Moderate High	Similar numbers of patients in both treatment groups were satisfied with their treatment and would repeat the procedure as reported by one study.
6. Return to work	**Very low** Low Moderate High	Greater proportion of multilevel C-ADR patients returned to part-time or full-time work and at a quicker rate than single-level C-ADR patients in one study.
Complications		
Outcomes	**Strength of evidence**	**Conclusions/comments**
1. Reoperation	**Very low** Low Moderate High	Reoperation was reported by three studies, one of which reported a lower rate at 2 years following single-level compared with multilevel C-ADR, and two studies reported similar reoperation rates between the groups.
2. Heterotopic ossification	**Very low** Low Moderate High	Two studies reported conflicting results for the rate of HO between groups.
3. Other complications	**Very low** Low Moderate High	A significantly lower incidence of dysphagia was reported following single-level compared with multilevel C-ADR at 2 years in one study. Rates of revision, device subsidence or migration, infection, mortality, and other complications were similar between groups.

CLINICAL GUIDELINES

No clinical guidelines were found.

CASE STUDY

- The patient is a 28-year-old man with cervical radiculopathy which affects the right C5 and bilateral C7 nerve roots. He has completed 4 months of conservative therapy including physical therapy and selective nerve root blocks and continues to have pain and bilateral triceps weakness.
- A sagittal T2-weighted MRI image is shown (**Fig 2**) as are axial T2 images at C4–5 and C6–7 which demonstrate neuroforaminal stenosis on the right side at C4–5 and both sides at C6–7 (**Figs 3 and 4**).
- Rather than undergo noncontiguous ACDF, the patient elected to undergo noncontiguous C-ADR. Postoperatively, the patient's upper extremity pain resolved and he remains free of pain 1 year after surgery (**Figs 5 and 6**).

DISCUSSION

Multilevel C-ADR vs multilevel ACDF (*Table 6*)
- Of principal clinical interest as represents potential scenario with clinical equipoise
- Single study suggests outcomes significantly improved with multilevel C-ADR vs ACDF
- Cannot recommend either multilevel C-ADR or ACDF on basis of single study

Single-level C-ADR vs multilevel C-ADR (*Table 7*)
- Results appear similar for functional outcome measures, success rate, and patient satisfaction
- Lower return to work rate after multilevel C-ADR potentially related to greater baseline disability, longer duration of symptoms before surgery.
- HO results confusing – unclear why HO would be more common after single-level surgery
- Higher rates of dysphagia after multilevel C-ADR expected because length and force of retraction on the esophagus and associated swelling likely contribute to dysphagia

Strengths:
- The question was reviewed systematically.

Fig 2 Midline sagittal T2 MRI image demonstrates evidence of disc herniation at C4–5 and C6–7 while the other motion segments appear relatively well-preserved.

Fig 3 Axial T2 MRI image at C4–5 demonstrates right-sided neuroforaminal stenosis secondary to disc herniation.

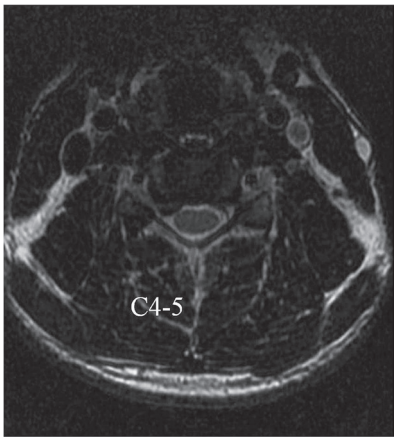
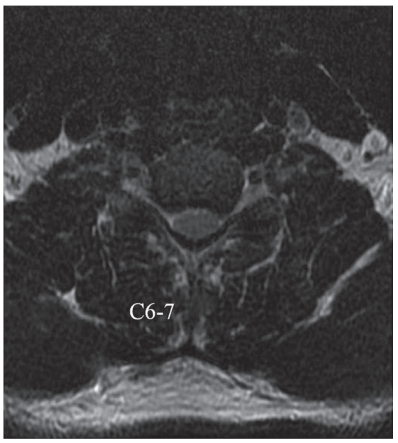


Fig 4 Axial T2 MRI image at C6–7 demonstrates bilateral neuroforaminal stenosis secondary to disc protrusion.



Limitations:

- Few studies available to address multilevel C-ADR vs multilevel fusion.
- Loss to follow-up was not reported in one study comparing multilevel C-ADR and fusion and in three studies comparing single-level vs multilevel C-ADR, possibly biasing results.
- No definition of clinically meaningful improvement in VAS or NDI was provided.
- Surveillance for and definitions of complications varied across studies.

Clinical relevance and impact

While there is insufficient evidence to make strong recommendations regarding the relative benefit of multilevel C-ADR vs multilevel ACDF, there conversely is no evidence suggesting that results after C-ADR are worse than after ACDF; more studies must be done to investigate whether there is a clinical role for multilevel C-ADR. More data is available to compare single-level and multilevel C-ADR; results after multilevel C-ADR appear similar to single-level C-ADR and do not demonstrate elevated reoperation or failure rates. Increase in dysphagia rate after multilevel C-ADR is to be expected compared with single-level C-ADR, a less invasive procedure. Studies with longer-term follow-up are necessary to evaluate the theoretical benefit of C-ADR in reducing ASD and to test whether results are as durable as after multilevel ACDF.

SUMMARY AND CONCLUSIONS

- Although the best available literature suggests multilevel C-ADR has a slight advantage over ACDF at short-term follow-up, there is insufficient evidence to make treatment recommendations.
- Multilevel C-ADR has similar results to single-level C-ADR at short-term follow-up.
- Dysphagia rates are higher after multilevel C-ADR compared with single-level C-ADR.

Fig 5 Anteroposterior postoperative x-ray demonstrates C4–5 and C6–7 disc replacements which are well-placed in midline.

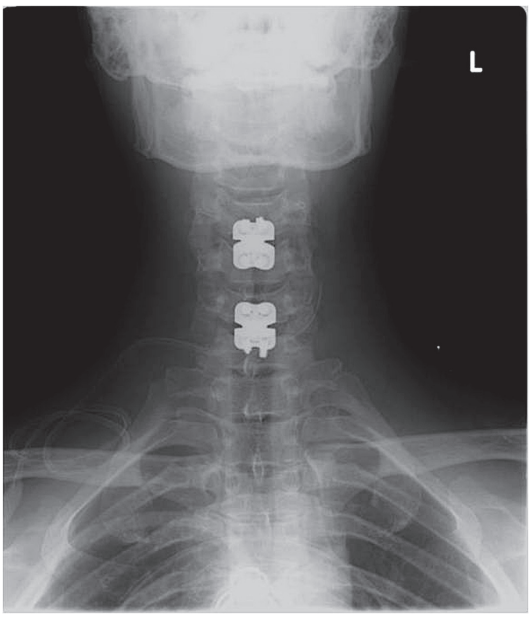


Fig 6 Neutral lateral postoperative x-ray demonstrates C4–5 and C6–7 disc replacements.

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