

Rising Adoption of Off-Label Three-Level Cervical Disc Replacement: Trends and Predictors

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INTRODUCTION: Anterior cervical discectomy and fusion (ACDF) remains the standard of care for multilevel cervical pathology but carries increased risk of pseudarthrosis and adjacent segment disease, which may necessitate reoperation. Cervical disc replacement (CDR) with its motion-preserving properties has demonstrated advantages over ACDF for one- and two-level procedures, yet three-level CDR remains off-label and understudied. This study aims to evaluate national utilization trends and identify predictors of three-level CDR.

METHODS: Patients undergoing three-level CDR or ACDF from 2015 to April 2023 were identified in the PearlDiver national database via CPT codes. Patients with trauma, malignancy, or infection were excluded. Primary outcomes included annual utilization trends for three-level CDR and ACDF. Percent change in utilization was calculated annually by comparing to the previous year and by comparing each year to 2015. Secondary outcomes compared demographic and procedural characteristics between cohorts. Multivariable logistic regression was performed to identify independent predictors of undergoing three-level CDR, adjusting for age, gender, and Elixhauser Comorbidity Index (ECI).

RESULTS SECTION: Among 82,458 included patients, 3,986 (4.8%) underwent three-level CDR and 78,472 (95.2%) underwent three-level ACDF. CDR patients were younger (50.0 vs 58.7 years, $p<0.001$), more likely male (47.5% vs 45.8%, $p=0.028$), had fewer comorbidities (ECI 3.29 vs 4.73, $p<0.001$), and higher household incomes (\$84,959 vs \$78,521, $p<0.001$). Three-level CDR utilization increased 197.9% from 2015 to 2022, with an average annual growth rate of 18.8% (Table 1; Figure 1). In 2015, three-level CDR accounted for 1.84% of all three-level anterior cervical procedures, rising to 6.13% by 2022. In contrast, three-level ACDF utilization declined from 2015 to 2018 and plateaued thereafter. Multivariable analysis identified independent predictors of three-level CDR, including age <40 years (aOR 3.47), male gender (aOR 1.14), cervical radiculopathy diagnosis (aOR 1.27), outpatient surgery (aOR 3.71), Midwest (aOR 1.19) or West region (aOR 2.32), higher education level (aOR 1.46), surgery by an orthopaedic surgeon (aOR 1.75), commercial insurance (aOR 1.65), and household income $> \$75,000$ (aOR 1.42) (all $p<0.001$; Figure 2).

DISCUSSION: Off label three-level CDR utilization has grown markedly since 2015. Its use is associated with younger, healthier, and socioeconomically advantaged patients, while older patients and those with public insurance are more likely to undergo ACDF. These findings highlight emerging disparities in access to this motion-preserving surgery, which may provide added benefit in younger patients.

SIGNIFICANCE/CLINICAL RELEVANCE: (1-2 sentences): This is the first large-scale analysis of national three-level CDR utilization. The rapid growth and socioeconomic disparities underscore the urgent need for prospective studies and regulatory review to guide coverage policies and ensure equitable access to this evolving surgical option.

Table 1. Annual Utilization Rates of ACDF and CDR

P-value	Three-Level ACDF Cases	% change since 2015	Annual % change	Three-Level CDR Cases	% change since 2015	Annual % change
	10,299	-		193	-	
	9,976	-3.14%	-3.14%	266	37.82%	37.82%
	9,184	-10.83%	-7.94%	410	112.44%	54.14%
	8,935	-13.24%	-2.71%	484	150.78%	18.05%
	9,718	-5.64%	8.76%	623	222.80%	28.72%
	9,040	-12.22%	-6.98%	602	211.92%	-3.37%
	9,976	-3.14%	10.35%	642	232.64%	6.64%
	8,800	-14.55%	-11.79%	575	197.93%	-10.44%
	2,737	-		193	-	

Figure 2: Predictors of Cervical Disc Replacement

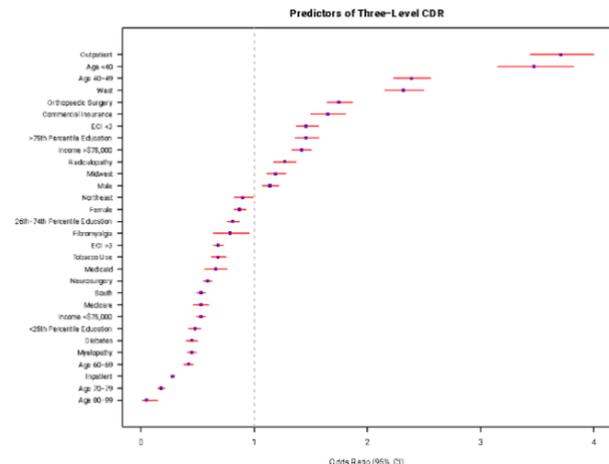


Figure 1: Annual Utilization Trends of Three-level CDR and ACDF from 2015-2022

