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Clinical Study

# Refining risk adjustment for bundled payment models in cervical fusions—an analysis of Medicare beneficiaries

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**Abstract**

**BACKGROUND CONTEXT:** The current Bundled Payment for Care Improvement model relies on the use of "Diagnosis Related Groups" (DRGs) to risk-adjust reimbursements associated with a 90-day episode of care. Three distinct DRG groups exist for defining payments associated with cervical fusions: (1) DRG-471 (cervical fusions with major comorbidity/complications), (2) DRG-472 (with comorbidity/complications), and (3) DRG-473 (without major comorbidity/complications). However, this DRG system may not be entirely suitable in controlling the large amounts of cost variation seen among cervical fusions. For instance, these DRGs do not account for area/location of surgery (upper cervical vs. lower cervical), type of surgery (primary vs. revision), surgical approach (anterior vs. posterior), extent of fusion (1−3 level vs. >3 level), and cause/indication of surgery (fracture vs. degenerative pathology).

**PURPOSE:** To understand factors responsible for cost variation in a 90-day episode of care following cervical fusions.

**STUDY DESIGN:** Retrospective study of a 5% national sample of Medicare claims from 2008 to 2014 5% Standard Analytical Files (SAF5).

**OUTCOME MEASURES:** To calculate the independent marginal cost impact of various patient-level, geographic-level, and procedure-level characteristics on 90-day reimbursements for patients undergoing cervical fusions under DRG-471, DRG-472, and DRG-473.

**METHODS:** The 2008 to 2014 Medicare SAF5 was queried using DRG codes 471, 472, and 473 to identify patients receiving a cervical fusion. Patients undergoing noncervical fusions (thoracolumbar), surgery for deformity/malignancy, and/or combined anterior-posterior fusions were excluded. Patients with missing data and/or those who died within 90 days of the postoperative follow-up period were excluded. Multivariate linear regression modeling was performed to assess the independent marginal cost impact of DRG, gender, age, state, procedure-level factors (including cause/indication of surgery), and comorbidities on total 90-day reimbursement.

**RESULTS:** Following application of inclusion/exclusion criteria, a total of 12,419 cervical fusions were included. The average 90-day reimbursement for each DRG group was as follows: (1) DRG-471=\$54,314±\$32,643, (2) DRG-472=\$28,535±\$17,271, and (3) DRG-473=\$18,492±\$10,706. The risk-adjusted 90-day reimbursement of a nongeriatric (age <65) female, with no major comorbidities,

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undergoing a primary 1- to 3-level anterior cervical fusion for degenerative cervical spine disease was $14,924±$753. Male gender (+$922) and age 70 to 84 (+$1,007 to +$2,431) was associated with significant marginal increases in 90-day reimbursements. Undergoing upper cervical surgery (−$1,678) had a negative marginal cost impact. Among other procedure-level factors, posterior approach (+$3,164), >3 level fusion (+$2,561), interbody (+$667), use of intra-operative neuromonitoring (+$1,018), concurrent decompression/laminectomy (+$1,657), and undergoing fusion for cervical fracture (+$3,530) were associated higher 90-day reimbursements. Severe individual comorbidities were associated with higher 90-day reimbursements, with malnutrition (+$15,536), CVA/stroke (+$6,982), drug abuse/dependence (+$5,059), hypercoagulopathy (+$5,436), and chronic kidney disease (+$4,925) having the highest marginal cost impacts. Significant state-level variation was noted, with Maryland (+$8,790), Alaska (+$6,410), Massachusetts (+$6,389), California (+$5,603), and New Mexico (+$5,530) having the highest reimbursements and Puerto Rico (−$7,492) and Iowa (−$3,393) having the lowest reimbursements, as compared with Michigan.

**CONCLUSIONS:** The current cervical fusion bundled payment model fails to employ a robust risk adjustment of prices resulting in the large amount of cost variation seen within 90-day reimbursements. Under the proposed DRG-based risk adjustment model, providers would be reimbursed the same amount for cervical fusions regardless of the surgical approach (posterior vs. anterior), the extent of fusion, use of adjunct procedures (decompressions), and cause/indication of surgery (fracture vs. degenerative pathology), despite each of these factors having different resource utilization and associated reimbursements. Our findings suggest that defining payments based on DRG codes only is an imperfect way of employing bundled payments for spinal fusions and will only end up creating major financial disincentives and barriers to access of care in the healthcare system. 

*Keywords:* Bundled payment; Cervical fusion; Risk adjustment; Medicare; Diagnosis Related Groups; Resource utilization

## Introduction

The cost of healthcare in the United States is one of the highest in the world, constituting more than 17% of the nation's gross domestic product in 2016 [1,2]. With the expansion of healthcare coverage under the Affordable Care Act [3], rise of economic growth and increase in longevity nationally, it is estimated that healthcare spending will continue to increase by at least 5.8% annually [4]. Such a trajectory is unsustainable, forcing health-policy makers to delve into innovative value-based approaches toward care to reduce the impending cost burden. Bundling payments, or "bundled payments," is an alternative payment model (APM) [5] that relies on the principle of reimbursing service providers out of one combined payment. Because multiple providers are sharing money out of a single predefined amount, bundled payments align the incentives of all providers, promotes care communication and interdisciplinary care in order to bring about quality in care while reducing cost variation in care across the entire spectrum.

Although bundled payments are slowly gaining in popularity across cardiac surgery [6] and total joint arthroplasties [7,8], the implementation of these APMs in spine surgery still remains a matter of debate. Many providers have voiced concerns regarding the inability of bundled payments to comprehensively control or risk-adjust payments to account for the cost variation and heterogeneity seen within spine surgeries [9−12]. The only current federal voluntary bundled payment model for cervical fusions, the Bundled Payment for Care Improvement (BPCI), relies on the use of three distinct Diagnosis Related Groups (DRGs) to identify/trigger episodes and define payments: (1) DRG-471 (cervical fusions with major comorbidity/complications), (2) DRG-472 (with comorbidity/complications), and (3) DRG-473 (without major comorbidity/complications). Although these DRGs do risk-adjust prices, to some degree, based on patient complexity/acuity, they are not inherently constructed to cater to the large amount of procedural heterogeneity seen within the types of cervical fusions being performed. For instance, these DRGs do not differentiate or risk-adjust episodes/prices based on the surgical approach (anterior vs. posterior), extent of fusion (1−3 level vs. >3 level), and diagnosis/indication of surgery (fracture vs. degenerative cervical spine pathology) despite each having varying perioperative resource utilization. Although the BPCI for spinal fusions is still in infancy stages, gathering historical cost data from various institutions across the United States to create stipulated 90-day retrospective bundled payment models, it is likely that results from this model will eventually be used to create a national mandatory bundled payment for spine surgery. Identifying and correcting/improving the ways of defining future bundled payments, early on, will play a key role in the success of such APM initiatives in the realm of spine surgery.

In an effort to support and facilitate discussions on improving bundled payments for spinal fusions, the current study aims to use a 5% national sample of Medicare beneficiaries from 2008 to 2014 to understand the impact of various patient-level, procedure-level, and geography-level factors on 90-day reimbursements following cervical fusions. The findings of the study will allow health-policy makers to better understand the importance of an enhanced risk adjustment approach toward defining future bundled payments among patients undergoing cervical fusions.

## Materials and methods

### *Database and patient sample*

The 2008 to 2014 Medicare 5% Standard Analytical Files (SAF5) was used for this study. The SAF5 database was accessed through the PearlDiver research software, which is a subscription-based HIPAA compliant "super-database" that houses research datasets from Humana, Nationwide Inpatient Sample, and Medicare. These datasets can be accessed through the PearlDiver user interface that relies on the use of a supercomputer to query and retrieve records for users [13]. Datasets can be queried using *Current Procedural Terminology* codes, International Classification of Disease 9th/10th (ICD-9/ICD-10) diagnosis/procedure codes, and DRG codes. Because data are already deidentified, the study was exempt from institutional review board approval.

DRG codes 471, 472, and 473 were used to identify patients undergoing cervical fusions from the SAF5 database. Patients undergoing noncervical spinal fusions, >8 level fusions, fusion for deformity/malignancy/infection, and combined anterior-posterior fusions were excluded from the study. A complete list of exclusion codes can be found in the Supplementary Appendix. Records were filtered to exclude patients who had missing follow-up starting from day 0 of surgery up to day 90 postoperatively. Patients who died during this 90-day time frame were also excluded. All payments made to service providers (hospitals, physicians, and postacute care) from day 0 of surgery up to day 90 postoperatively were used to calculate 90-day reimbursements. The terms "reimbursements" refer to the actual payments made by Medicare to the hospital and are used interchangeably throughout the manuscript.

Patient level factors that were analyzed as part of the study included age, gender, and comorbidities. Procedure-level factors included approach (anterior vs. posterior), location (upper cervical/C1−C2 vs. lower cervical/below C2), type of surgery (primary vs. revision), extent of fusion (1−3 level vs. >3 level), use of interbody device, use of bone graft, use of bone morphogenetic protein (BMP-2), use of intraoperative neuromonitoring, concurrent decompression/laminectomy, and cause/indication of surgery (fracture vs. degenerative cervical spine pathology). Geography-level factors included the state where the surgery was performed. A complete list of ICD-9 diagnosis and procedure codes used to identify comorbidities and procedure-level factors can be found in the Supplementary Appendix.

### *Statistical analysis*

Multivariate linear regression analyses were used to calculate the independent marginal cost impact (increase/decrease) of individual patient-level, procedure-level and geography-level factors on 90-day reimbursements while controlling for all other covariates. Results from multivariate linear regression analyses have been reported as adjusted marginal cost impacts (+/−) in US dollars ($), along with their standard errors and p values. Significance was set at p value of ≤.05 for all comparisons. Even though more than 50 state-level comparisons were made, no Bonferroni correction was applied as these comparisons were largely exploratory. All statistical analyses were performed using the PearlDiver research software, which uses R statistics at the back-end to produce results for their users.

## Results

Following application of inclusion/exclusion criteria, a total of 12,419 cervical fusions were included, out of which 902 (7.3%) were in DRG-471, 2,969 (N=23.9%) in DRG-472, and 8,548 (68.8%) in DRG 473. The average 90-day reimbursement for each DRG group was as follows: (1) DRG-471=$54,314±$32,643, (2) DRG-472=$28,535±$17,271, and (3) DRG-473=$18,492±$10,706 (Table 1).

The risk-adjusted 90-day reimbursement of a nongeriatric (age <65) female, with no comorbidities, undergoing a primary 1- to 3-level anterior cervical fusion for degenerative cervical spine disease was $14,924±$753. Male gender (+$922) and patients lying within age groups of 70 to 74 years (+$1,007), 75 to 79 years (+$1,402), and 80 to 84 years (+$2,431) were associated with significant marginal increases in 90-day reimbursements (Table 2).

With regard to procedure-level factors, receiving a posterior versus anterior surgical approach (+$3,164), >3 level fusion versus 1- to 3-level fusion (+$2,651), use of interbody device (+$667), intraoperative neuromonitoring (+$1,018), concurrent decompression/laminectomy (+$1,657), and undergoing fusion for cervical fracture versus degenerative cervical spine pathology (+$3,530) had significant marginal increases in 90-day reimbursements (Table 3). Of note, undergoing upper cervical surgery (C1−C2) versus lower cervical surgery (below C2) was associated with lower 90-day reimbursements (−$1,678). Comorbidities associated with significant marginal cost-increases were malnutrition (+$15,536), Cerebrovascular disease/stroke (+$6,982), drug abuse/dependence (+$5,059), hypercoagulopathy (+$5,436), and chronic kidney disease (+$4,925), anemia (+$3,953),

Table 1
Average 90-day costs all cervical fusions

| | Number of patients | 90-day average costs |
|---|---|---|
| DRG-471 (with MCC) | 902 | $54,314±$32,643 |
| DRG-472 (with CC) | 2,969 | $28,535±$17,271 |
| DRG-473 (without MCC or CC) | 8,548 | $18,492±$10,706 |

Reimbursements reported have not been risk-adjusted for any parameter.

Table 2
Marginal cost impacts of individual DRG, gender, and age groups on 90-day costs/payments

| | Number of patients | Marginal cost impact (+/−) | p value* |
|---|---|---|---|
| DRG group | | | |
| 471 | 902 | +$23,596±$753 | **<.001** |
| 472 | 2,969 | +$5,630±$314 | **<.001** |
| 473 | 8,548 | Ref. | – |
| Gender | | | |
| Female | 6,576 | Ref. | |
| Male | 5,843 | +$922±$265 | **<.001** |
| Age | | | |
| <65 | 4,439 | Ref. | – |
| 65−69 | 3,391 | −$105±$333 | .753 |
| 70−74 | 2,273 | +$1,007±$381 | **.008** |
| 75−79 | 1,348 | +$1,402±$457 | **.002** |
| 80−84 | 664 | +$2,431±$610 | **<.001** |
| ≥85 | 304 | +$847±$867 | .328 |

All reported costs have been risk-adjusted for DRG, gender, age, state, and procedure-level factors. The p values represent comparison to reference groups as specified.
* p values in bold indicate statistical significance.

malignancy (+ $2,356), depression/bipolar disorder (+ $1,313), diabetes mellitus (+$1,279), obesity (+$1,171), anxiety disorder (+$794), and chronic obstructive pulmonary disease (+$631; Table 4). Significant state-level variation in 90-day reimbursements was also seen, with Maryland (+ $8,790), New Jersey (+$8,060), Alaska (+$6,410), Massachusetts (+$6,389), California (+$5,603), and New Mexico (+$5,530) having the highest marginal cost impacts, as compared with Michigan. Surgeries performed in Puerto Rico (−$7,942), Iowa (−$3,393), Oklahoma (−$3,112), Wisconsin (−$2,862), Alabama (−$2,703), Tennessee (−$2,014), and Ohio (−$1,933) had the lowest marginal cost impacts, as compared with the Michigan (Table 5).

## Discussion

The use of DRGs to identify, trigger and risk-adjust bundled payments for spinal fusions has long been criticized by spine surgeons. Most of the concerns voiced by providers are related to the failure of DRG-based bundled payment models to robustly account for the different diagnoses/cause/indications, treatment modalities and complexity seen within spinal fusions [14]. Using a nationally representative dataset of Medicare beneficiaries, the current study identifies numerous patient-level, procedure-level, and geography-level factors that significantly contribute to the cost variation seen within DRG-defined 90-day episodes of care following cervical fusions. The data support the need/requirement of an enhanced risk adjustment approach for defining future bundled payments in cervical fusions to ensure that care is equitable and accessible for all.

As mentioned previously, the current BPCI model relies on the use of three distinct DRG-codes to identify/trigger episodes and define payments. The classification of patients into these DRG codes is largely dependent on patient complexity and/or the development of complications during the inpatient stay, with DRGs having comorbidity/complication modifiers having different payments. For example, the average nonrisk adjusted payment for a patient falling under DRG-473 (cervical fusion, without major/nonmajor comorbidity/complications) is $18,492, whereas that of patients falling under DRG-472 and DRG-471 was successively higher (DRG-472=$28,535 and DRG-471=$54,314). Although these modifiers may risk-adjust payments based on patient complexity, they do not properly account for

Table 3
Marginal cost impact of procedural-level factors on 90-day costs/payments while controlling for DRG, gender, state, and comorbidities

| | Number of patients | Marginal cost impact (+/−) | p value* |
|---|---|---|---|
| Area/location of surgery | | | |
| Upper cervical (C1−C2) | 441 | −$1,678±$801 | **.036** |
| Lower cervical (below C2) | 11,978 | Ref. | – |
| Type of surgery | | | |
| Revision | 258 | −$1,724±887 | .052 |
| Primary | 12,161 | Ref. | – |
| Surgical approach | | | |
| Posterior | 2,100 | +$3,164±$425 | **<.001** |
| Anterior | 10,319 | Ref | – |
| Extent of fusion | | | |
| 1−3 level | 2,763 | Ref. | – |
| >3 level | 9,656 | +$2,561±315 | **<.001** |
| Use of interbody | 6,264 | +$667±$265 | **.012** |
| Use of bone graft | 3,859 | +$250±$277 | .367 |
| Use of BMP | 887 | −$246±$490 | .615 |
| Use of intraoperative neuromonitoring | 1,325 | +$1,018±$412 | **.013** |
| Concurrent decompression/laminectomy | 581 | +$1,657±$602 | **.006** |
| Undergoing fusion for cervical fracture | 767 | +$3,530±$623 | **<.001** |

* p values in bold indicate statistical significance.

Table 4
Marginal cost impacts of individual comorbidities on 90-day costs/payments while controlling for DRG, gender, state, procedure level factors, and diagnosis of fracture

| Comorbidity | Number of patients | Marginal cost impact (+/−) | p value |
|---|---|---|---|
| Congestive heart failure | 734 | +\$3,556±\$563 | **<.001** |
| Ischemic heart disease | 2,524 | +\$328±\$335 | .327 |
| Hyperlipidemia | 5,013 | −\$396±\$271 | .144 |
| Hypertension | 8,418 | +\$209±\$287 | .466 |
| Parkinson disease | 135 | +\$4,595±\$1,200 | **<.001** |
| Alzheimer disease | 191 | +\$1,479±\$1,045 | .157 |
| Cerebrovascular/stroke | 1,316 | +\$6,982±\$447 | **<.001** |
| Chronic obstructive pulmonary disease (COPD) | 3,015 | +\$631±\$300 | **.035** |
| Diabetes mellitus | 3,426 | +\$1,279±\$295 | **<.001** |
| Hypothyroidism | 1,809 | −\$529±\$362 | .144 |
| Chronic kidney disease | 913 | +\$4,925±\$521 | **<.001** |
| Chronic liver disease | 249 | +\$886±\$898 | .323 |
| Malignancy | 517 | +\$2,356±\$630 | **<.001** |
| Inflammatory disorder | 760 | +\$831±\$524 | .113 |
| Coagulopathy | 286 | −\$20±\$849 | .981 |
| Hypercoagulopathy | 41 | +\$5,436±\$2,174 | **.012** |
| Osteoporosis | 1,525 | +\$631±\$409 | .123 |
| Obesity | 619 | +\$1,171±\$580 | **.044** |
| Anemia | 1,424 | +\$3,953±\$428 | **<.001** |
| Alcohol use | 69 | −\$863±\$1,691 | .609 |
| Tobacco use | 2,155 | −\$681±\$352 | .053 |
| Drug Abuse | 228 | +\$5,059±\$937 | **<.001** |
| Depression/bipolar | 2,683 | +\$1,313±\$338 | **<.001** |
| Anxiety disorder | 1,809 | +\$794±\$388 | **.041** |
| Malnutrition | 206 | +\$15,536±\$1,021 | **<.001** |

p values in bold indicate significance.

procedure complexity leading to significant amount of cost variation reported between the DRGs. As noted in our findings, posterior cervical fusions were associated with more than $3000 higher risk-adjusted reimbursements across the 90-day episode of care as compared with anterior fusions. This is likely due to the fact that posterior cervical fusions on average have higher postoperative resource care utilization, as evidenced by longer length of stay, higher rates of blood transfusions, and increased odds of nonhome discharges to facilities [15−17]. Using the Medicare database, Virk et al. created stipulated bundled payment models for patients undergoing fusions for cervical spondylotic myelopathy and found that the average reimbursements for all service providers (hospital, surgeon, anesthesiologists, and postacute care facilities) were higher in patients undergoing posterior cervical fusions as compared with anterior cervical fusions [18]. Undergoing C1 to C2 fusion was associated with a nearly $1,700 risk-adjusted lower payment as compared with subaxial cervical fusions, further questioning the inclusion of atlantoaxial fusions within the same DRG bundle as subaxial/lower cervical fusions. Similarly, complex cases such as >3 level fusion and adding concurrent laminectomy/decompression had around $1,600 to $2,500 higher risk-adjusted reimbursements. Current evidence regarding the value of the BPCI bundled payment models in cervical fusions is largely limited. Odum et al. carried a historical cost and outcome analysis of cervical fusions being performed under BPCI model and found that patients enrolled in the BPCI model had higher 90-day reimbursements as compared with the non−BPCI cervical fusions [19]. The authors attributed the results to the inability of cervical fusion DRGs to account for the large amount of heterogeneity and complexity seen within various cervical fusions. A similar lack of cost savings has also been reported in other BPCI literature on lumbar fusions, further supporting our viewpoints on DRG-only risk adjustments being a poor way to define bundled payments in spinal fusions.

It is interesting to note that using adjunct procedures such as intraoperative neuromonitoring increasing the 90-day risk-adjusted reimbursement by more than $1,000. As the current healthcare model transitions toward adoption of value-based approaches, providers and health policy makers should strongly advocate for a judicious use of neuromonitoring given that recent literature has either failed to reveal a significant reduction in neurologic events [20−22] or has not provided sufficient high-grade evidence [23] to recommend/support the use in routine anterior cervical spine surgeries. Limiting the use of such adjunct neuromonitoring for critical cases, such as C1 to C2 fusions, fracture fixations, and/or patients presenting with severe cervical myelopathy may be a possible way of lowering the reimbursements in a bundled payment model.

More importantly, undergoing fusion for a cervical fracture was associated with a more than $3,500 addition in the

Table 5
Marginal cost impacts of state on 90-day costs/payments while controlling for DRG, gender, comorbidities, procedure level factors, and diagnosis of fracture

| State | Number of patients | Marginal cost impact (+/−) | p value* |
|---|---|---|---|
| Alabama | 418 | −$2,703±$946 | **.004** |
| Arkansas | 139 | −$762±$1,343 | .571 |
| Kansas | 134 | −$2,367±$1,360 | .082 |
| Oklahoma | 266 | −$3,112±$1,076 | **.004** |
| Louisiana | 241 | −$1,747±$1,107 | .115 |
| Florida | 913 | −$1,371±$804 | .088 |
| Tennessee | 447 | −$2,014±$929 | **.030** |
| Utah | 100 | −$2,107±$1,529 | .168 |
| Iowa | 93 | −$3,393±$1,573 | **.031** |
| Missouri | 378 | −$1,183±$969 | .222 |
| Mississippi | 204 | −$1,997±$1,172 | .088 |
| Georgia | 502 | −$1,773±$905 | .050 |
| North Dakota | 40 | −$1,102±$2,274 | .628 |
| Montana | 62 | −$3,192±$1,872 | .088 |
| Ohio | 475 | −$1,933±$914 | **.034** |
| South Carolina | 331 | −$1,814±$1,005 | .071 |
| South Dakota | 55 | −$2,607±$1,973 | .186 |
| Idaho | 123 | −$1,836±$1,410 | .193 |
| Texas | 1,103 | +$86±$781 | .912 |
| Nebraska | 93 | −$541±$1,574 | .731 |
| Kentucky | 205 | −$1,092±$1,167 | .349 |
| Virginia | 319 | −$1,263±$1,016 | .214 |
| Nevada | 154 | +$1,431±$1,293 | .269 |
| Pennsylvania | 390 | −$128±$960 | .894 |
| Indiana | 312 | −$655±$1,023 | .522 |
| Wisconsin | 115 | −$2,862±$1,444 | **.048** |
| North Carolina | 531 | −$1,660±$891 | .063 |
| Maine | 47 | +$130±$2,113 | .951 |
| New Mexico | 38 | +$5,530±$2,331 | **.018** |
| Oregon | 145 | −$551±$1,320 | .676 |
| Wyoming | 24 | +$164±$2,890 | .955 |
| Minnesota | 170 | −$1,489±$1,248 | .233 |
| Illinois | 515 | +$412±$950 | .664 |
| Delaware | 50 | +$1,080±$2,058 | .599 |
| West Virginia | 64 | −$1,567±$1,844 | .395 |
| Colorado | 219 | −$551±$1,144 | .630 |
| Arizona | 200 | +$2,621±$1,180 | **.026** |
| New Jersey | 165 | +$8,080±$1,260 | **<.001** |
| Rhode Island | 29 | +$2,769±$2,643 | .295 |
| Washington | 265 | +$733±$1,076 | .495 |
| New Haven | 46 | −$1,360±$2,134 | .524 |
| Connecticut | 123 | +$2,341±$1,406 | .096 |
| Hawaii | 15 | +$4,463±$3,616 | .217 |
| New York | 414 | +$3,389±$947 | **<.001** |
| Vermont | 12 | −$2,328±$4,027 | .563 |
| District of Columbia | 55 | +$3,578±$1,974 | .070 |
| Massachusetts | 200 | +$6,389±$1,178 | **<.001** |
| California | 856 | +$5,603±$813 | **<.001** |
| Alaska | 25 | +$6,410±$2,833 | **.024** |
| Maryland | 248 | +$8,790±$1,096 | **<.001** |
| Puerto Rico | 16 | −$7,942±$3,509 | **.024** |
| Michigan (Ref.) | 335 | – | – |

Adjustments and p values represent comparison to Michigan.
* p values in bold indicate statistical significance.

risk-adjusted 90-day reimbursement. Although no study has yet evaluated differences in outcomes and resource utilization between patients undergoing fusion for cervical fracture versus degenerative cervical spine pathology, similar observations have been reported in the arthroplasty bundled payment realm. During the initial phases of Comprehensive Joint Replacement model, providers and health-policy makers began to realize that hospitals and physicians who regularly performed total hip arthroplasties (THAs) for fractures were being unfairly penalized. Though these fracture patients had higher rates of medical and surgical complications, longer hospital stays, increased non-home discharges to facility and subsequent greater 90-day reimbursements, hospitals, and surgeons were being paid the same lump-sum amount of money as that for an elective THA [24−27]. As the evidence against the unfair payments amounted, the Center for Medicare and Medicaid Services eventually revised and risk-adjusted the bundle to ensure that providers taking care of hip fracture patients undergoing THAs had subsequently higher reimbursements. With more than 6% (N=767) of cervical fusions being performed for fractures in the current study, along with a rising national incidence of cervical spine trauma across the United States [28], these findings strongly question the inclusion of fracture patients into the same bundle as degenerative cervical spine pathologies. Risk-adjusting or creation of separate bundled payments, based on fracture status of patient, along with presence/absence and/or degree/severity of associated spinal cord injury would be an effective way of ensuring providers are being appropriately reimbursed based on the case complexity of patients they take care of. Conversely, it is also important to mention that Center for Medicare and Medicaid Services will use historical administrative claims data to calculate prices of episodic bundles and it is probable that granular clinical factors such as the absence/presence and/or degree/severity of spinal cord injuries may not be comprehensively available in an administrative claims dataset. Irrespective, this further supports excluding these fracture patients from an elective cervical fusion bundle.

Numerous comorbidities, including several potential modifiable ones such as malnutrition, obesity, anemia, diabetes mellitus, and chronic obstructive pulmonary disease, were associated with higher risk adjusted 90-day reimbursements. Understanding the reimbursements of the potential modifiable comorbidities is particularly valuable as this can incentivize providers to aim for appropriate preoperative optimization in elective patients to save a significant amount of money in a bundled environment. For instance, delaying elective cervical fusion and placing malnourished patients on appropriate preoperative nutritional management may reduce the odds of these patients experiencing potentially avoidable complications such as surgical site infections [29]. Chronic obstructive pulmonary disease has previously been shown to affect postoperative outcomes following elective anterior cervical fusions [30]. Appropriate preoperative pulmonary protocols and/or involvement of pulmonologists in medical comanagement of these patients may ultimately reduce the need of extra resource utilization in a bundle. Similarly with the presence of diabetes was associated with nearly $1,300 addition in risk-adjusted 90-day reimbursements, optimizing diabetic individuals to reduce HbA1c levels below 7.5 before carrying out elective fusions would be an ideal approach to reducing the risks of infections and subsequent reimbursements in a bundle [31]. From a health-policy perspective, these findings also call into question the grouping of multiple comorbidities under one broad DRG modifier to define payments (with/without comorbidities/complications) given that different comorbidities have varying reimbursements and resource utilization requirements. This is particularly relevant in cases where the comorbidity present is a nonmodifiable one (stroke=+$6,982 vs. congestive heart failure=+ $3,556), and patients cannot be preoperatively optimized. The lack of appropriate risk adjustment to ensure sicker patients get higher payments may lead to providers “cherry-picking” simpler cases while “lemon-dropping” complex ones in order to profit from the net-margins instead of losing money in a bundle.

A significant amount of state-level variation was seen in 90-day reimbursements. Briefly summarizing, it appears that certain states in the Northeast (Massachusetts, Maryland, New York, and New Jersey) and West (California and Alaska) had on average, $5,000 to $9,000 additional risk-adjusted 90-day payments as compared with Michigan. There are a couple of reasons for the higher reimbursements of care seen within these regions. First, the higher hospital overhead costs (utilities, rent, etc.) in certain expensive/concentrated states (Maryland, New York, etc.) may be influencing the significantly higher payments observed. For remote states such as Alaska, a smaller number of medical providers and low hospital market concentration are possible factors driving the high reimbursements of care. Although all current BPCI models are based on institutional pricing and some degree of regional cost variation, it is likely that these significant state-level cost variations would also need to be adjusted for when developing a risk-adjusted bundled payment model on the national scale.

The study has several limitations, most of which are related to the use of administrative claims datasets. Although we employed the use of a nationally representative Medicare claims, these datasets are often prone to miscoding errors. We also did not carry out a comprehensive adjustment for inflation when calculating the risk-adjusted reimbursements in our study, and it is probable that the payments reported may actually be a true underestimate of current healthcare reimbursements. However, given that main objective of the study was to identify and report factors associated with cost variation seen within cervical fusion DRGs, we believe the results are well equipped to facilitate discussion on the need of an enhanced risk adjustment method toward defining future prospective bundled payments. We also did not account for various other patient-level factors such socioeconomic status, education level of individual, median household income, and availability of caregiver that may also influence the outcomes and reimbursements in a bundle. From a statistical perspective, we did not choose to apply a Bonferroni correction to account for the multiple comparisons seen in our state-level analyses. Our reported state-level cost variation, for the most part, is in accordance with that reported across literature [32], and applying a more conservative p value would have resulted in losing significance for several of our findings.

In conclusion, the current BPCI DRG-based bundled payment model for cervical fusions is poorly risk-adjusting payments as providers would be reimbursed the same amount of money irrespective of the surgical approach (anterior vs. posterior), location (upper cervical vs. lower cervical), extent of fusion (1−3 level vs. >3 level), and cause/indication of surgery (fracture vs. degenerative cervical spine pathology) despite each of these factors having varying resource utilization in the peri- and postoperative period. Moving forward, health policy makers and providers should advocate for revising the current DRG-based bundled payment model by including individual patient-level, state-level, and procedure-level factors to risk-adjust prospective payments to prevent the creation of a financial disincentive in taking care of sicker patients and/or performing more extensive complex spinal fusions.

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## Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.spinee.2019.06.009.

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