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Indications for spine surgery: validation of an administrative coding algorithm to classify degenerative diagnoses

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Abstract

Study Design—Retrospective analysis of Medicare claims linked to a multi-center clinical trial.

Objective—The Spine Patient Outcomes Research Trial (SPORT) provided a unique opportunity to examine the validity of a claims-based algorithm for grouping patients by surgical indication. SPORT enrolled patients for lumbar disc herniation, spinal stenosis, and degenerative spondylolisthesis. We compared the surgical indication derived from Medicare claims to that provided by SPORT surgeons, the “gold standard”.

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Summary of Background Data—Administrative data are frequently used to report procedure rates, surgical safety outcomes, and costs in the management of spinal surgery. However, the accuracy of using diagnosis codes to classify patients by surgical indication has not been examined.

Methods—Medicare claims were link to beneficiaries enrolled in SPORT. The sensitivity and specificity of three claims-based approaches to group patients based on surgical indications were examined: 1) using the first listed diagnosis; 2) using all diagnoses independently; and 3) using a diagnosis hierarchy based on the support for fusion surgery.

Results—Medicare claims were obtained from 376 SPORT participants, including 21 with disc herniation, 183 with spinal stenosis, and 172 with degenerative spondylolisthesis. The hierarchical coding algorithm was the most accurate approach for classifying patients by surgical indication, with sensitivities of 76.2%, 88.1%, and 84.3% for disc herniation, spinal stenosis, and degenerative spondylolisthesis cohorts, respectively. The specificity was 98.3% for disc herniation, 83.2% for spinal stenosis, and 90.7% for degenerative spondylolisthesis. Misclassifications were primarily due to codes attributing more complex pathology to the case.

Conclusion—Standardized approaches for using claims data to accurately group patients by surgical indications has widespread interest. We found that a hierarchical coding approach correctly classified over 90% of spine patients into their respective SPORT cohorts. Therefore, claims data appears to be a reasonably valid approach to classifying patients by surgical indication.

Keywords

Low Back Pain; Administrative Data; Lumbar Spine Surgery; Sensitivity and Specificity

INTRODUCTION

Researchers have frequently used administrative data to report population-based procedure rates, surgical safety outcomes, and costs in the diagnosis and management of back pain related conditions.[1-5] Under key provisions of the Affordable Care Act, they are also increasingly used to design reimbursement reforms such as bundled payment contracts.[6] These efforts frequently rely on algorithms based on diagnosis and procedure codes from the International Classification of Disease, 9th Revision, Clinical Modification (ICD-9-CM) or procedure codes from the American Medical Association's *Current Procedural Terminology* (CPT).[7-9] However, critics have questioned the accuracy of administrative data to characterize trends in spine surgery, arguing that that they are prone to mis-classification, lack clinical detail, and useful only for billing purposes.[10-12] While previous studies have reported the validity of select codes for identifying certain spinal procedures, their validity in classifying surgical indications has not been previously reported.[13, 14] Furthermore, because patients undergoing spine surgery often have multiple degenerative diagnoses, they frequently have multiple spine-related diagnosis codes, which leads to ambiguity as to which is the most relevant surgical indication. There is no standardized approach for using claims data to group patients into clinically meaningful groups based on surgical indication, and the selective use of codes can result in biased reporting.

The quality of the information provided by a diagnostic test that is used to discriminate between two or more groups of patients is often reported as the sensitivity and specificity of the classification method relative to a gold standard.[15] A major limitation in classifying patients into groups based on surgical indication has been the lack of an acceptable gold standard based on surgeon diagnostic and physical evaluation. Data from the Spine Patient Outcomes Research Trial (SPORT) provided a unique opportunity to examine the validity of using diagnosis codes to classify patients by surgical indication.[16-18] We report the sensitivity and specificity of the surgical indication derived from claims, compared to that provided by surgeons who enrolled patients in SPORT, which served as our "gold standard." In essence, we used the claims as a "diagnostic test" for the primary SPORT indication for surgery. We further compared three different approaches to classifying SPORT surgical patients based on administrative data: 1) relying on the first listed ("primary") diagnosis only, 2) searching all listed diagnoses associated with a patient's admission and creating independent non-mutually exclusive variables for each diagnosis indication ("All diagnoses"), and 3) searching all listed diagnoses associated with a patient's admission and grouping them into a mutually-exclusive hierarchy for surgical indication ("All diagnoses, hierarchy").

METHODS

Data source

SPORT is a unique multi-center randomized trial comparing non-operative care to surgery for three distinct cohorts: disc herniation, spinal stenosis, and degenerative spondylolisthesis. A parallel observational cohort was enrolled using exactly the same protocol except treatment was determined by patient choice. Details of SPORT have been reported elsewhere.[16-18] Consenting participants enrolled into one of the three SPORT cohorts. Rigorous inclusion and exclusion criteria, including imaging confirmation of pathoanatomy, shared-decision making, and surgeon examination provided a high degree of confirmation of the surgical indication. We used this indication as the gold standard for comparing claims-based approaches. SPORT surgical patients over age 65, from both randomized and prospective cohort studies were included in our analysis.

Medicare claims

We linked Medicare claims by patient age, sex, zip code of residence, and date of surgery to the SPORT participants over age 65, including all inpatient (Part A) and provider (Part B) line item claims to provide a complete accounting of the ICD-9-CM diagnosis and CPT codes for these patients. We included claims submitted for services provided between three days prior to, and seven days following, the date of the SPORT surgery. We included only patients who had Medicare eligibility through the Old Age and Survivors Insurance (OASI) program, excluding those with eligibility through the Social Security Disability Insurance (SSDI), End Stage Renal Disease (ESRD), or Medicare HMO programs.

We obtained ethical approval for this study from the Committee for the Protection of Human Subjects at Dartmouth, as well as a data use approval from the Centers for Medicare and Medicaid Services.

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Claims algorithm

Once the diagnosis codes in the claims were obtained for each Medicare beneficiary in SPORT, we classified each patient by surgical indication based on a coding algorithm (Table 1). To develop the algorithm, we identified ICD-9-CM diagnosis codes that are commonly used to describe abnormal symptoms and diagnoses among patients with spine-related problems. Spinal operations and vertebral regions involved were further defined by using ICD-9 and CPT procedure codes. Spine-related ICD-9-CM diagnosis codes were identified by searching the annual updates published every October by the World Health Organization.[7] We also referenced the Conversion Tables of New ICD-9-CM Codes published by the National Center for Health Statistics to help identify newly added or modified codes. New code assignments are defined by the ICD-9-CM Coordination and Maintenance Committee. CPT codes are a registered trademark of the American Medical Association and are designed to inform insurers and epidemiologists about the medical services that are provided to patients by providers. Relevant CPT codes were identified through a search of the CPT Assistant Archives, an electronic publication available from the AMA.[19]

The selected codes were then used to define seven diagnostic categories: 1) degenerative diseases, 2) fracture or dislocation (including osteoporotic compression fracture), 3) spinal cord injury, 4) congenital or other spinal anomaly, 5) inflammatory spondylopathy, 6) osteoporosis (not necessarily spine-specific), and 7) surgical aftercare (including codes for mechanical failure of orthopaedic device). Codes identified as involving degenerative disease were further sub-divided into six clinically meaningful groups and ordered into hierarchy for surgical indication (described below).

Classification approach

Using the “primary” approach, we relied on only the first listed diagnosis code to classify patients in a group based on surgical indication. The first listed diagnosis code is sometimes deemed to be the most important reason for an admission, depending on the data source.

Using the “All Diagnoses” approach, we searched all listed diagnosis codes associated with a patient's admission and created non-mutually exclusive variables for each of the surgical indication groups. Essentially, each patient is characterized by a combination of 5 binary indicator variables that correspond to the diagnoses for back pain, disc herniation, spinal stenosis, spondylolisthesis and scoliosis. If any of the diagnosis codes for a given patient fits the definition for a particular surgical indication group, the indicator variable for that group is set to positive. Under this approach, a patient may have multiple diagnoses (e.g. a patient may have a positive indicator for stenosis and a positive indicator for spondylolisthesis). While this approach is useful for analyzing the overlap of surgical pathology, it is not practical for differentiating a population by a primary surgical indication because patients may be assigned to multiple groups.

The Hierarchical approach builds on the All Diagnoses approach. This involved searching all listed diagnosis codes associated with a patient's admission and grouping them into a mutually-exclusive hierarchy according to the strength of evidence for performing spinal fusion, ordered as: 1) muscle sprains/strains (least supported), 2) non-specific back pain (includes spondylosis and degenerative discs), 3) herniated disc (with or without myelopathy), 4) spinal stenosis, 5) spondylolisthesis, and 6) scoliosis (most supported). Evidence reviews suggest only weak support for fusion surgery in back pain due to degenerative discs, with no benefit over structured non-operative treatments. Fusion appears to be more effective for treating deformity, such as degenerative spondylolisthesis, fractures, and scoliosis, but has been shown to improve outcomes over decompression in patients with disc herniation or spinal stenosis.

Because SPORT only recruited lumbar surgical candidates, we used a separate set of indicator variables to restrict our analysis to those claims involving the thoracolumbar, lumbar, or lumbosacral regions. With the exception of select codes for orthopaedic devices and osteoporosis, diagnosis codes that were not specifically spine-related (e.g. “psychogenic pain”) were not included in the algorithm.

Analysis

The classification of surgical indication based on the administrative coding algorithm was compared to the diagnosis provided by the SPORT enrolling surgeons using two by two tables for each cohort. All cases from the coding algorithm that were not concordant with their respective SPORT surgical cohort were treated as a misclassification. Discordant cases in the hierarchical approach were inspected to identify opportunities to optimize the algorithm. In particular, we inspected the frequency of all diagnosis codes when the hierarchical algorithm appeared to understate the specific pathology. For example, we listed diagnoses that were coded among those enrolled in SPORT for degenerative spondylolisthesis, but which the hierarchical algorithm classified as spinal stenosis.

For each of the three claims-based classification approaches, we then reported the sensitivity and specificity when compared against the SPORT cohort as the gold standard for surgical indication. Sensitivity refers to the proportion of patients within each SPORT surgical cohort who were correctly classified by the algorithm as having the diagnosis. For example, it represents the proportion of SPORT surgical patients with a disc herniation who were correctly classified as having a disc herniation by the algorithm (calculated as the true-positive cases from the algorithm divided by the sum of the true-positive cases and falsely-negative cases). Specificity refers to the proportion of patients outside of each SPORT cohort who were correctly classified by the algorithm as not having the respective diagnosis. For example, it represents the proportion of patients who were correctly counted as not having a disc herniation by our algorithm (the number of true negatives divided by the sum of the true-negatives and false-positives).

Our algorithm included a category for scoliosis, which was not a SPORT cohort. Patients with more than 15 degrees of curvature were excluded from all the SPORT cohorts. Therefore, any scoliosis identified by the algorithms was likely to be mild and clinically insignificant. Therefore, a separate analysis was performed by reclassifying patients using the hierarchical approach while ignoring scoliosis as a diagnosis category.

RESULTS

We successfully linked 376/468 (80.3%) of SPORT surgery patients over age 65 to Medicare claims, including 21 (5.6%) with a disc herniation, consistent with this not being a common diagnosis among older adults, 183 (48.7%) with spinal stenosis, and 172 (45.7%) with degenerative spondylolisthesis. In addition to their degenerative diagnosis, a small proportion of patients in each SPORT cohort also had diagnosis codes for non-degenerative spinal problems (appendix A).

Based on a comparison of the sensitivity and specificities, the hierarchical coding approach was better at correctly classifying SPORT surgical stenosis patients, compared to either the primary diagnosis approach or the All Diagnosis approach (Table 2). The three approaches were similar for classifying disc herniation, while the All Diagnosis approach was slightly better than the hierarchical approach for identifying degenerative spondylolisthesis.

Table 3 provides the cross-classifications between the claims-based hierarchical coding algorithm and the SPORT Medicare patients for each cohort. The sensitivity for the hierarchical coding algorithm was 76.2%, 88.1%, and 84.3% for disc herniation, spinal stenosis, and degenerative spondylolisthesis cohorts, respectively. The specificity of the algorithm was 98.3% for disc herniation, 83.2% for spinal stenosis, and 90.7% for degenerative spondylolisthesis. Excluding the scoliosis group from the algorithm resulted in a slight improvement to classification for stenosis and degenerative spondylolisthesis.

We inspected the listings of ICD-9-CM diagnosis codes among patients for whom the hierarchical coding algorithm understated the specific pathology relative to the SPORT gold standard. For example, of the 172 patients with degenerative spondylolisthesis, 27 (15.7%) were misclassified by the algorithm into another group. Of these 27 cases, 7 were grouped into as scoliosis, and 20 as spinal stenosis or back pain. Table 4 details the frequency of spine-related ICD-9-CM diagnosis codes that were listed among those cases in which the algorithm underreported the pathology (grouped into a lower tier of the hierarchy). There were 25 spine-related diagnosis codes among the 20 underreported patients with degenerative spondylolisthesis; code 724.02 (“spinal stenosis, lumbar without claudication”) was the most frequently listed code.

CONCLUSIONS

A claims-based hierarchical coding algorithm of spine-related medical encounters correctly classified over 90% of Medicare patients into their respective SPORT cohorts. The hierarchical approach classifies patients into a surgical indication group based on the examination of all available diagnosis codes for a patient. An obvious concern with classifying patients using the hierarchical approach is that a mild, incidental, or ancillary diagnosis that is coded may not best reflect the true indication for surgery. Similarly, relying on the Primary or the All Diagnoses approaches, may also fail to capture the patient's true indication and desire for surgery. Even when surgical treatment is supported by a valid indication, it may be inconsistent with a patients values when well informed about treatment options and associated risks. The protocol for SPORT was more rigorous than previous spine surgery studies. Taking the surgical indication provided by the enrolling surgeons in SPORT as the gold standard, we found that the hierarchical coding algorithm generally out-performed the other two approaches.

Misclassifications were fairly infrequent with this approach. In the spinal stenosis cohort they were primarily due to the algorithm attributing more severe pathology (e.g. degenerative spondylolisthesis) to the patient. Among the degenerative spondylolisthesis cohort, the algorithm was more likely to understate than to overstate the specific pathology based on the hierarchy.

The use of a coding algorithm for reporting rates or counts of admission would be unbiased if the false-negative classification rate was equal to the false-positive classification rate; that is, if the rates of these misclassifications cancelled each other out. In our analysis of the SPORT spinal stenosis and degenerative spondylolisthesis cohorts, the false positive rate was slightly lower than the false negative rate. This finding suggests that the hierarchical coding algorithm is more likely to slightly underreport these two diagnoses than it is to over report them.

This study was limited by the relatively small sample of SPORT participants who were also Medicare beneficiaries, particularly, but expected, for the disc herniation cohort. We were unable to link Medicare claims for about 20% of the SPORT participants over age 65. These patients may have been Medicare-HMO, not available in OASI claims, or had claims that were submitted outside the period of time that we linked claims to patients. While we accepted SPORT as the gold standard for classifying surgical indications, a true gold standard may be elusive given the heterogeneity of symptoms and pathology.[20] There is likely to be some overlap in diagnoses and misclassification in identifying the true source of pain among SPORT participants. Furthermore, because SPORT patients derived from highly specialized spinal practices, they may not be representative of typical spine surgery patients. It is possible that coding practices among these specialized spine practices, participating in a federally funded trial, are more accurate than that of a typical practice. The meaning for some spine-related ICD-9-CM procedure codes change on occasion over time, requiring careful attention to avoid inaccuracy, particularly in longitudinal studies. However, the definitions for spine-related ICD-9-CM diagnosis codes are more stable over time. Finally, we were unable to validate algorithms for classifying non-specific back pain or scoliosis because these were not included in the SPORT study.

Future efforts should focus on exploring ways to further optimize the algorithm, and to develop similar algorithms incorporating the changes with the adoption of ICD-10 codes in 2014. For example, the use of importance weighting based on commonly used codes, or their location in the claim, may improve the classification. Researchers should also seek to validate claims-based approaches for characterizing spine-related utilization (including manual therapy, imaging, percutaneous procedures, and surgery), as well as spine surgical safety outcomes, perhaps through comparisons with chart reviews. Finally, analyses involving the use of claims-based algorithms would be strengthened by discussing the findings and conclusions with respect to the measurement errors that we report. Understanding the rates of misclassification when grouping spine surgery patients by surgical indication may be informative to future observational research that relies on claims data.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Claims-based classification of patients with spine-related medical encounters into clinically meaningful diagnosis and spinal region groups based on codes from the International Classification of Diseases, 9th revisions, Clinical Modification and *Current Procedural Terminology Codes (CPT)*.

GROUP	CATEGORY		VARIABLE NAME	CODING	CODES
Diagnosis	Degenerative (subcategories are ordered in a mutually-exclusive hierarchy from least to most specific pathology)	Sprains/strains	DEGDX=1 (Hierarchy); SPINEDX1	DEGDX = 1; 0 = No; 1 = Yes	***ICD-9 Diagnosis codes*** 846.0 846.1 846.2 846.3 846.8 846.9 847 847.9 847.2 847.0
		Back pain (axial pain and spondylosis)	DEGDX=2 (Hierarchy); SPINEDX2	DEGDX = 2; 0 = No; 1 = Yes	***ICD-9 Diagnosis codes*** 723 723.8 723.1 721.0 721.1 721.2 721.3 721.4721.7 721.8 721.9 721.90 721.91 722.4 722.5722.51 722.52 722.6 722.90 722.92 722.91 722.93 724.2 724.5 724.6 724.70 724.71 724.79 724.8 724.9
		Herniated without myelopathy	DEGDX=3 (Hierarchy); SPINEDX3	DEGDX = 3; 0 = No; 1 = Yes	***ICD-9 Diagnosis codes*** 722.0 722.10 722.11 722.2
		Herniated with myelopathy	DEGDX=4 (Hierarchy); SPINEDX4	DEGDX = 4; 0 = No; 1 = Yes	***ICD-9 Diagnosis codes*** 353.9 355.0 355.9 722.70 722.71 722.72 722.73 724.3 721.4 724.4
		Stenosis	DEGDX=5 (Hierarchy); SPINEDX5	DEGDX = 5; 0 = No; 1 = Yes	***ICD-9 Diagnosis codes*** 721.42 721.91 724.00 724.02 724.09 723.0 724.01
		Listhesis	DEGDX=6 (Hierarchy); SPINEDX6	DEGDX = 6; 0 = No; 1 = Yes	***ICD-9 Diagnosis codes*** 738.4 756.11 756.12
		Scoliosis	DEGDX=7 (Hierarchy); SPINEDX7	DEGDX = 7; 0 = No; 1 = Yes	***ICD-9 Diagnosis codes*** 737.39 737.3 737.30 737 737.20 737.8 737.9 737.1 737.10 737.19 737.32 737.34 737.43
	Spinal fracture or dislocation		SPINEDX8	0 = No; 1 = Yes	***ICD-9 Diagnosis codes*** 733.1 733.10 733.13 733.8 733.81 733.82 733.95 805 805.0 805.00 805.01 805.02 805.03805.04 805.05 805.06 805.07 805.08 805.1 805.10 805.11

GROUP	CATEGORY		VARIABLE NAME	CODING	CODES
					805.12 805.13 805.14 805.15 805.16 805.17 8 805.12 805.13 805.14 805.15 805.16 805.17 8
	Spinal Cord Injury	SPINEDX9	0 = No; 1 = Yes	***ICD-9 Diagnosis codes*** 336.9952.0 952.00 952.03 952.05 952.09 952.10952.9 953.0 952.04	
	Congenital or other spinal anomaly	SPINEDX10	0 = No; 1 = Yes	***ICD-9 Diagnosis codes*** 324.1 344.60 721.5 721.6 721.7 722.30 722.32 723.7 724.6 727.40 733.20 738.5 739.3 739.4 741.90 754.2 756.10 756.13 756.14 756.15 756.16 756.17 756.19	
	Inflammatory spondylopathy	SPINEDX11	0 = No; 1 = Yes	***ICD-9 Diagnosis codes*** 720.0 720.1 720.2 720.8 720.81 720.89 720.9	
	Osteoporosis	SPINEDX12	0 = No; 1 = Yes	***ICD-9 Diagnosis codes*** 733.0 733.00 733.01 733.02 733.03 733.09 V17.81 V82.81	
	Surgical aftercare/ revision / previous surgery (Spine related codes that imply previous spine procedure)	SPINEDX13	0 = No; 1 = Yes	***CPT codes*** 0098T 0165T 22861 22862 62350 62351 63660 63688 64585 64595 11982 11983 20665 20670 20680 22850 22852 22855	

GROUP	CATEGORY		VARIABLE NAME	CODING	CODES
				22864 22865 62355 62365 63660 63688 64585 64595 22864 22865 62355 62365 63660 63688 64585 64595 ***ICD-9 Diagnosis codes*** 722.80 722.81 722.83 874.9 996.67 E878.1 996.2 996.59 996.4 996.40 996.41 996.49 998.59 V45.4 996.78 ***ICD-9 Procedure codes*** 81.09 81.30 81.31 81.32 81.33 81.34 81.35 81.36 81.37 81.38 81.39 03.94 03.97 03.98 78.6 78.60 78.69 84.81 03.02 84.83 84.85 84.66 84.67 84.68 84.69	
Region	Atlas/Axis	REG_A	0 = No; 1 = Yes	***CPT codes*** 22318 22319 22548 22590 22595 ***ICD-9 Diagnosis Codes*** 805.01 805.02 805.11 805.12 839.01 839.02 839.11 839.12 ***ICD-9 Procedure Codes*** 81.01 81.31	
	Cervical	REG_C	0 = No; 1 = Yes	***CPT Codes*** 0092T 63300 63304 22856 22861 22864 63001 63015 63051 63075 63076 63081 63082 63180 63182 63265 63270 63275 0095T 0098T 20660 20661 20664 20665 21899 22100 22110 22210 22220 22326 22554 22600 63040 63043 63045 63194 63196 63198 63250 63280 63285 72040 72050 72052 72126 72127 72141 72142 72147 72156 72125 63020 63050 ***ICD-9 Diagnosis Codes*** 847.0 721.0 721.1 722.4 722.91 723* 723.1 723.8 722.0 722.71 723.0 722.81 805.0 805.00805.03 805.04 805.05 805.06 805.07 805.08 805.1 805.10 805.13 805.14 805.15 805.16 805.17 805.18 806.0 806.00 806.01 806.02806.03 806.04 806.05 806.06 806.07 806.08806.09 806.1 806.10 806.11 806.12 806.13 806.14 806.15 806.16806.17 806.18 806.19 839.0 839.00 839.03839.04 839.05 839.06 839.07 839.08 839.1839.10 839.13 839.14 839.15 839.16 839.17839.18 952.0 952.00 952.00 952.03 952.09953.0 723.7 952.04 ***ICD-9 Procedure Codes*** 93.52 93.41 87.22 81.02 81.03 81.32 81.33 84.61 84.62 84.66	
	Cervico-thoracic	REG_CT	0 = No; 1 = Yes	***CPT Codes*** 64470 64470 64470 64470 64472 64479 64480 92291 22010 62281 62310 62318 72285 64491 64493 ***ICD-9 Procedure Codes*** 87.23 84.63 84.67	
	Thoracic	REG_T	0 = No; 1 = Yes	***CPT codes***	

GROUP	CATEGORY		VARIABLE NAME	CODING	CODES
				63085 63086 63197 63199 63266 63271 63276 63286 63287 63077 63078 63016 63055 6306 63085 63086 63197 63199 63266 63271 63276 63286 63287 63077 63078 63016 63055 6306 63085 63086 63197 63199 63266 63271 63276 63286 63287 63077 63078 63016 63055 6306 63085 63086 63197 63199 63266 63271 63276 63286 63287 63077 63078 63016 63055 6306 63085 63086 63197 63199 63266 63271 63276 63286 63287 63077 63078 63016 63055 6306 63085 63086 63197 63199 63266 63271 63276 63286 63287 63077 63078 63016 63055 6306 63085 63086 63197 63199 63266 63271 63276 63286 63287 63077 63078 63016 63055 6306 63085 63086 63197 63199 63266 63271 63276 63286 63287 63077 63078 63016 63055 6306 ***ICD-9 Diagnosis Codes*** 721.2 722.51 722.92 722.11 722.72 724.01 737.34 805.2 805.3 806.2 806.20 806.21 806.22 806.23 806.24 806.25 806.26 806.27 806.28 806.29 839.21 952.10 806.3 806.30 806.31 806.32 806.33 806.34 806.35 806.36 806.37 806.38 806.39 862.8 862.8 ***ICD-9 Procedure Codes*** 81.04 81.05 81.34 81.35	
	Thoracolumbar	REG_TL	0 = No; 1 = Yes	***CPT codes*** 22522 22525 22534 63057 63087 63088 63103 63252 63302 63306 64520 72069 72080 ***ICD-9 Diagnosis Codes*** 721.4 722.5 839.2 839.3	
	Lumbar	REG_L	0 = No; 1 = Yes	***CPT Codes*** 63042 63044 63047 63056 63200 63267 63272 63277 63017 63030 63005 62287 22865 22862 22625 22630 22612 22533 22524 22521 0163T 0164T 0165T 22102 22114 22207 22214 22224 22325 22558 62290 62292 63012 63282 64714 72131 72133 72148 72149 72158 72295 0171T 0172T 72295 ***ICD-9 Diagnosis codes*** 722.93 724.2 721.42 722.10 722.73 724.02 722.83 805.4 805.5 806.4 806.5 839.20 739.3 839.30 847.2	
	Lumbosacral	REG_LS	0 = No; 1 = Yes	***CPT Codes*** 22015 62311 62319 63303 63307 64475 64476 64483 64484 64622 64623 72100 72110 72114 72120 62311 64494 94495 ***ICD-9 Diagnosis codes*** 846.0 721.3 722.52 724.4 756.11 846.0 ***ICD-9 Procedure codes*** 84.64 84.65 84.68 87.24 81.06 81.07 81.08 81.36 81.37 81.38	
	Sacral	REG_S	0 = No; 1 = Yes	***CPT Codes*** 63278 63283 63268 63273 27096 62282 63011 63283 72200 72202 72220 ***ICD-9 Diagnosis codes*** 846.1 846.3 846.8 846.9 724.6 724.70 724.71724.79 805.6 805.7 806.6 806.60	

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GROUP	CATEGORY		VARIABLE NAME	CODING	CODES
				806.61 806.62 806.69 806.7 806.70 806.71 806.72806.79 739.4 806.61 806.62 806.69 806.7 806.70 806.71 806.72806.79 739.4	

Table 2

Administrative coding algorithm performance characteristics for grouping patients by indication for surgery relative to SPORT diagnosis, including sensitivity and specificity for each classification approach.

		SPORT cohort		
Coding Algorithm for Classifying Surgical Indication	**Performance characteristic**	**Disc Herniation**	**Spinal Stenosis**	**Degenerative Spondylolisthesis**
Primary diagnosis	Sensitivity (95%CI)	81.0 (58.1, 94.6)	74.3 (67.4, 80.5)	32.0 (25.1, 39.5)
	Specificity	94.9 (92.1, 97.0)	51.3 (44.0, 58.5)	96.1 (92.4, 98.3)
All Diagnoses	Sensitivity	95.2 (76.2, 99.9)	95.1 (90.9, 97.7)	87.8 (81.9, 92.3)
	Specificity	80.6 (76.1, 84.6)	16.6 (11.6, 22.6)	90.2 (85.3, 93.9)
All Diagnoses, Hierarchy	Sensitivity	76.3 (52.8, 91.8)	88.1 (82.2, 92.6)	84.3 (78.0, 89.4)
	Specificity	98.3 (96.4, 99.4)	83.2 (77.4, 88.0)	90.7 (85.8, 94.3)
All Diagnoses, Hierarchy (excluding scoliosis)	Sensitivity	76.2 (52.8, 91.8)	86.3 (80.5, 91.0)	87.8 (81.9, 92.3)
	Specificity	98.3 (96.4, 99.4)	89.1 (83.8, 93.1)	90.2 (85.3, 93.9)

Table 3

Summary of the cross-classification of three SPORT gold standard cohorts with the hierarchical claims-based diagnosis algorithm.

			SPORT cohort (gold standard)		
Hierarchical Claims-based coding algorithm	***Herniated Disc***		***Yes***	***No***	***Total***
		Yes	16 (4.3%)	6 (1.6%) *SPORT enrolled 6 as spinal stenosis*	22
		No	5 (1.3%) *Algorithm understated 1 as back pain; and overstated 3 as spinal stenosis, 1 as degenerative spondylolisthesis*	349 (92.8%)	354
		Total	21	355	376
	Spinal stenosis	***Yes***	148 (39.4%)	20 (5.3%) *SPORT enrolled 3 as disc herniation, 17 as degenerative spondylolisthesis*	168
		No	35 (9.3%) *Algorithm understated 6 as disc herniation; and overstated 18 as degenerative spondylolisthesis, 11 as scoliosis*	173 (46.0%)	208
		Total	183	193	376
	Degenerative spondylolisthesis	***Yes***	145 (38.6%)	19 (5.1%) *SPORT enrolled 1 as disc herniation, 18 as spinal stenosis*	159
		No	27 (7.2%) *Algorithm understated 3 as back pain, 17 as spinal stenosis; and overstated 7 as scoliosis*	185 (49.2%)	197
		Total	172	204	376

Table 4

Frequency listing of all diagnosis codes among discordant cases in which the hierarchical coding algorithm underestimated the specific pathology.

SPORT cohort					
Disc herniation		**Spinal Stenosis**		**Degenerative spondylolisthesis**	
Listing of spine-related icd-9-cm codes in cases where the hierarchical algorithm underreported SPORT diagnosis of disc herniation (n = 1)		**Listing of spine-related icd-9-cm codes in cases where the hierarchical algorithm underreported SPORT diagnosis of spinal stenosis (n = 6) [1]**		**Listing of spine-related icd-9-cm codes in cases where the hierarchical algorithm underreported SPORT diagnosis of degenerative spondylolisthesis (n = 20)**	
codes	**Listed diagnosis**	**codes**	**Listed diagnosis**	**codes**	**Listed diagnosis**
1	721.3 lumbosacral spondylosis	3	722.10 lumbar disc displacement	11	724.02 spin sten, lumbr wo claud
1	722.52 lumb/lumbosac disc degen	1	722.73 lumb disc dis w myelopat	4	733.00 osteoporosis nos
1	729.5 Pain in limb			3	721.3 lumbosacral spondylosis
				2	722.52 lumb/lumbosac disc degen
				2	727.40 synovial cyst nos
				1	997.01 surg complication - cns
				1	714.0 rheumatoid arthritis
				1	V57.1 physical therapy nec

[1] 6 patients incurred 4 spine-related diagnosis codes, implying that some patients had codes that were not spine-specific based on hierarchical algorithm.