

Clinical Study

National trends in the surgical treatment for lumbar degenerative disc disease: United States, 2000 to 2009

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Abstract

BACKGROUND CONTEXT: Surgical treatment for lumbar degenerative disc disease (DDD) remains controversial. Options include anterior lumbar interbody fusion, posterior approach fusion procedures such as posterior lumbar interbody fusion (PLIF) and posterolateral lumbar fusion (PLF), anterior and posterior lumbar fusion (APLF), and total disc replacement (TDR). However, the trends during the last decade are uncertain.

PURPOSE: To examine the trends in the surgical treatment for lumbar DDD on a national level.

STUDY DESIGN: A retrospective analysis of population-based national hospital discharge data collected for the Nationwide Inpatient Sample (NIS).

PATIENT SAMPLE: In the NIS from 2000 to 2009, patients aged 18 years or older with primary diagnosis of lumbar/lumbosacral DDD who underwent surgical treatment were included.

OUTCOME MEASURES: Trends in the surgical treatment for lumbar DDD.

METHODS: Clinical data were derived from the NIS between 2000 and 2009. Patients aged 18 years or older with a primary diagnosis of lumbar/lumbosacral DDD who underwent spinal fusion or TDR were identified. Data regarding patient- and health care system-related characteristics were retrieved and analyzed.

RESULTS: A total of 380,305 patients underwent surgical treatment for lumbar DDD between 2000 and 2009. Population adjusted incidence increased 2.4-fold from 2000 to 2009. Among the procedures, APLF increased 3.0-fold and PLIF/PLF increased 2.8-fold. Total disc replacement did not increase significantly. Anterior lumbar interbody fusion was performed in 16.8% of patients, PLIF/PLF in 67.9%, APLF in 13.6%, and TDR in 1.8%. Surgical treatment for lumbar DDD was 1.8 times more common in the Midwest region and 1.7 times more common in the South region than in the Northeast region. Total disc replacement was more common in younger patients and in the Northeast region. Posterior lumbar interbody fusion/PLF was more common in older patients and in the South region.

CONCLUSIONS: During the last decade, surgical treatment for lumbar DDD has increased 2.4-fold in the United States. Although all fusion procedures significantly increased, TDR did not increase. Surgical treatment for lumbar DDD was more common in the Midwest and South regions. Trends in the procedures were different depending on the age group and hospital region. © 2015 Elsevier Inc. All rights reserved.

Keywords:

Lumbar degenerative disc disease; Surgical treatment; Trend; Spinal fusion; Total disc replacement; Nationwide Inpatient Sample

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Introduction

Surgical treatment for lumbar degenerative disc disease (DDD) remains controversial [1]. The mainstay of treatment for lumbar DDD are conservative treatments such as activity modification, medications, and physical therapy,

EVIDENCE & METHODS

Context

A number of studies have determined that the use of spine surgery, and spinal fusion in particular, has increased dramatically over the last two decades. The authors sought to explore this issue further using 10 years worth of data from the Nationwide Inpatient Sample (NIS).

Contribution

More than 380,000 spine surgeries were performed for lumbar degenerative disc disease from 2000–2009, representing more than two-fold increases in the use of spine surgery for lumbar degenerative disc disease as a whole, as well as the performance of 360-degree fusion and posterior lumbar fusions.

Implications

This investigation adds to a growing body of literature highlighting the increased use of surgery, as well as fusion-based procedures, as treatment for degenerative conditions of the spine. Given the limitations of the NIS dataset, the authors cannot account for the population-at-risk (eg, the entire population of individuals with lumbar degenerative conditions). In light of the aging demographic and the increased prevalence of musculoskeletal disease, as well as enhanced access to medical care, an increase in surgical interventions for spinal conditions might be anticipated to a certain extent. The population adjustments employed by the authors cannot truly account for this. Clearly, this is an important issue warranting further research, with a keen focus on the clinical contexts in which such surgical interventions occur.

—The Editors

and some studies have identified negative outcomes after surgical treatment. Knox and Chapman [2] found poor results in two-level fusions and in almost half (47%) of single-level fusions for lumbar DDD. Carragee et al. [3] also reported that only 43% of patients undergoing spinal fusion for lumbar DDD met the criteria for minimum acceptable outcome. In contrast, the Swedish Lumbar Spine Study Group found that fusion for lumbar DDD results in superior outcomes relative to standard nonsurgical care [4].

Surgical options for lumbar DDD include anterior lumbar interbody fusion (ALIF), posterior approach fusion procedures such as posterior lumbar interbody fusion (PLIF) and posterolateral lumbar fusion (PLF), anterior and posterior lumbar fusion (APLF), and total disc replacement (TDR). Posterior lumbar interbody fusion and PLF are popular procedures for spinal surgeons performing lumbar surgery. A

variety of surgical techniques and innovative procedures have been introduced during the last decade. Recent ALIF techniques include anterior cage with screws and extreme/direct-lateral interbody fusion (XLIF/DLIF) with or without plates [5,6]. Anterior lumbar interbody fusion with percutaneous pedicle screw fixation has also gained popularity during the last decade [7]. In the middle of last decade, lumbar TDR was approved in the United States [8], which may have changed the trend in surgical management of lumbar DDD. However, trends in the surgical treatment for lumbar DDD during the last decade are uncertain in the United States.

The purpose of this study was to examine the trends in the surgical treatment for lumbar DDD using population-based national hospital discharge data collected for the Nationwide Inpatient Sample (NIS) between 2000 and 2009. We hypothesized that the incidence of patients with lumbar DDD undergoing surgical treatment had increased over the last decade and the surgical trends would have changed with the introduction of TDR and other innovative surgical and instrumentation techniques.

Methods

Data source

The NIS is the largest all-payer inpatient care database in the United States and contains data of approximately 8 million hospital stays from 1,000 hospitals each year. These data comprise a 20% stratified sample of all US community hospitals [9]. Each entry in the database represents a single hospitalization record. Records in the NIS database include discharge data and hospital information, which were used to generate national estimates in this analysis.

Patient selection

Our study samples were retrospectively obtained from the NIS between 2000 and 2009, using codes from the International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM). Patients aged 18 years or older with primary diagnosis of lumbar or lumbosacral DDD (772.52) were included in the study. Then patients were divided into those who underwent ALIF (81.06), PLIF/PLF (81.07 and/or 81.08), APLF (81.06 and 81.07–81.08), and TDR (84.65). Patients who underwent XLIF/DLIF were grouped with those undergoing ALIF. Patients who underwent transforaminal lumbar interbody fusion (TLIF) were grouped with those undergoing PLIF.

Patient- and health care system-related characteristics and patient outcomes

Patient age, gender, race, comorbidities, hospital size, hospital teaching status, hospital region, and payer information were extracted from the NIS. Patients were categorized into the following four groups according to the age: 18 to 44

Table

Demographics and hospital characteristics of patients with lumbar degenerative disc disease who underwent surgical treatment

Total number of cases	380,305							
	ALIF		PLIF/PLF		APLF		TDR	
Number of cases (% total)	63,853 (16.8)		258,206 (67.9)		51,552 (13.6)		6,694 (1.8)	
Mean age (y) (SD)	45.8 (11.3)		53.5 (13.7)		48.2 (12.0)		40.7 (8.9)	
	WF	%	WF	%	WF	%	WF	%
Age (y)								
18–44	31,219	48.9	72,883	28.2	21,200	41.1	4,384	65.5
45–64	28,473	44.6	124,438	48.2	24,963	48.4	2,291	34.2
65–84	4,107	6.4	59,583	23.1	5,335	10.3	19	0.3
≥85	54	0.1	1,302	0.5	54	0.1	0	0.0
Gender								
Male	27,536	43.1	117,583	45.5	24,292	47.1	3,477	51.9
Female	36,281	56.8	140,530	54.4	27,260	52.9	3,153	47.1
Race								
White	39,825	62.4	163,633	63.4	32,064	62.2	4,765	71.2
Black	2,620	4.1	11,213	4.3	1,854	3.6	190	2.8
Hispanic	2,586	4.0	9,328	3.6	2,686	5.2	327	4.9
Others	1,622	2.5	5,907	2.3	1,643	3.2	265	4.0
Not stated	17,200	26.9	68,125	26.4	13,305	25.8	1,147	17.1
Smoking habits								
Nonsmoking	50,695	79.4	210,617	81.6	41,410	80.3	5,530	82.6
Smoking	13,157	20.6	47,589	18.4	10,142	19.7	1,164	17.4
Weight								
Obesity	3,410	5.3	16,367	6.3	3,189	6.2	232	3.5
Morbid obesity	1,061	1.7	6,307	2.4	1,174	2.3	53	0.8
Others*	59,382	93.0	235,532	91.2	47,189	91.5	6,409	95.7
Elixhauser comorbidity score								
0	30,815	48.3	89,858	34.8	20,573	39.9	3,825	57.1
1	17,732	27.8	74,836	29.0	14,660	28.4	1,786	26.7
2	9,254	14.5	50,740	19.7	9,006	17.5	686	10.2
3	3,904	6.1	26,426	10.2	4,498	8.7	264	3.9
4 or more	2,149	3.4	16,347	6.3	2,814	5.5	134	2.0
Hospital size								
Small	8,632	13.5	31,229	12.1	9,120	17.7	1,186	17.7
Medium	15,075	23.6	56,484	21.9	11,628	22.6	1,524	22.8
Large	39,921	62.5	169,365	65.6	30,734	59.6	3,979	59.4
No information	225	0.4	1,128	0.4	70	0.1	5	0.1
Hospital teaching status								
Nonteaching	29,625	46.4	135,297	52.4	25,307	49.1	3,030	45.3
Teaching	34,003	53.3	121,781	47.2	26,174	50.8	3,660	54.7
No information	225	0.4	1,128	0.4	71	0.1	4	0.1
Hospital region								
Northeast	9,121	14.3	27,633	10.7	7,739	15.0	1,726	25.8
Midwest	20,490	32.1	65,134	25.2	15,669	30.4	1,300	19.4
South	22,514	35.3	113,259	43.9	13,937	27.0	2,122	31.7
West	11,728	18.4	52,179	20.2	14,208	27.6	1,546	23.1
Payer information								
Medicare	7,800	12.2	72,054	27.9	7,940	15.4	226	3.4
Medicaid	3,887	6.1	12,292	4.8	2,453	4.8	208	3.1
Private	39,062	61.2	133,511	51.7	29,858	57.9	3,668	54.8
Others	12,756	20.0	39,806	15.4	11,071	21.5	2,558	38.2

ALIF, anterior lumbar interbody fusion; PLIF, posterior lumbar interbody fusion; PLF, posterolateral lumbar fusion; APLF, anterior and posterior lumbar fusion; TDR, total disc replacement; WF, weighted frequency; SD, standard deviation.

* Underweight, normal weight, and overweight.

years, 45 to 64 years, 65 to 84 years, and older than 84 years. Patients were also categorized according to the race as white, black, Hispanic, others, and not stated. Patients with smoking habits were identified with ICD-9-CM diagnostic codes 305.1 and 305.10 to 305.13. Patients were categorized into obesity (278.00), morbid obesity (278.01), and others

(underweight, normal weight, or overweight). Comorbidity was assessed using the Elixhauser method, which is a well-established technique for identifying comorbidities from administrative databases [10]. Elixhauser comorbidity index includes a set of 30 medical comorbidities. Total comorbidity score was determined for each case by adding 1 point per

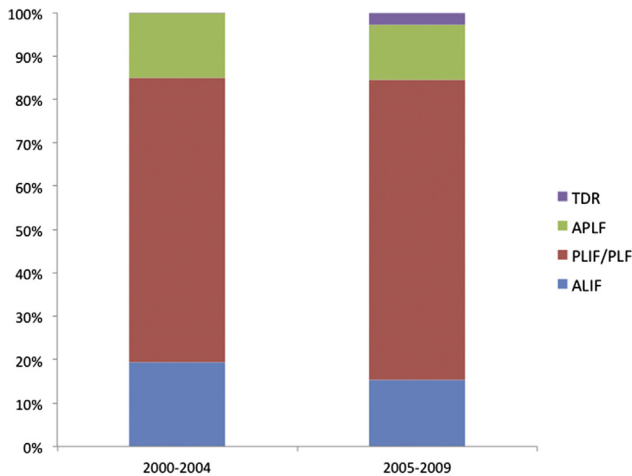


Fig. 1. Proportions of procedures in patients who underwent surgical treatment for lumbar degenerative disc disease between 2000 and 2004 and 2005 and 2009. TDR, total disc replacement; APLF, anterior and posterior lumbar fusion; PLIF, posterior lumbar interbody fusion; PLF, posterolateral lumbar fusion; ALIF, anterior lumbar interbody fusion.

comorbidity. Hospital size (bed number) was categorized into small, medium, and large, whereas hospital teaching status was categorized into nonteaching and teaching. Hospital census region was categorized into Northeast, Midwest, South, and West, and the payer information was categorized into Medicare, Medicaid, private, and others.

Data analysis

To calculate national estimates using the NIS, discharge weights supplied by the Federal Agency for Healthcare Research and Quality were applied. Categorical patient data were retrieved. United States and regional population data

between 2000 and 2009 were obtained from the US Census Bureau Web site [11]. The incidence of spinal fusion or TDR for lumbar DDD for a given year was adjusted for the overall population by dividing the national or regional estimates by the total or regional population estimates obtained from the US Census Bureau data for that year. A linear regression model was applied to analyze the time trend. Statistical analyses were performed with R version 2.15.1 (Free Software Foundation’s GNU General Public License, Boston, MA, USA). A p value of .05 was used to define a significant difference.

Results

Between 2000 and 2009, there were 380,305 patients with primary diagnosis of lumbar/lumbosacral DDD who underwent surgical treatment (Table). Among them, ALIF was performed in 63,853 patients (16.8%), PLIF/PLF in 258,206 patients (67.9%), APLF in 51,552 patients (13.6%), and TDR in 6,694 patients (1.8%). The mean age was 45.8 years for patients undergoing ALIF, 53.5 years for those undergoing PLIF/PLF, 48.2 years for those undergoing APLF, and 40.7 years for those undergoing TDR.

Coding for TDR started at the end of 2004. Between 2000 and 2004, ALIF was performed in 19.4% of patients, PLIF/PLF in 65.6%, APLF in 14.9%, and TDR in 0.1% (Fig. 1). Between 2005 and 2009, ALIF was performed in 15.3% of patients, PLIF/PLF in 69.2%, APLF in 12.8%, and TDR in 2.7%.

The number of patients with lumbar DDD who underwent surgical treatment increased over time: from 21,223 in 2000 to 55,467 in 2009 (p<.001). Population-adjusted

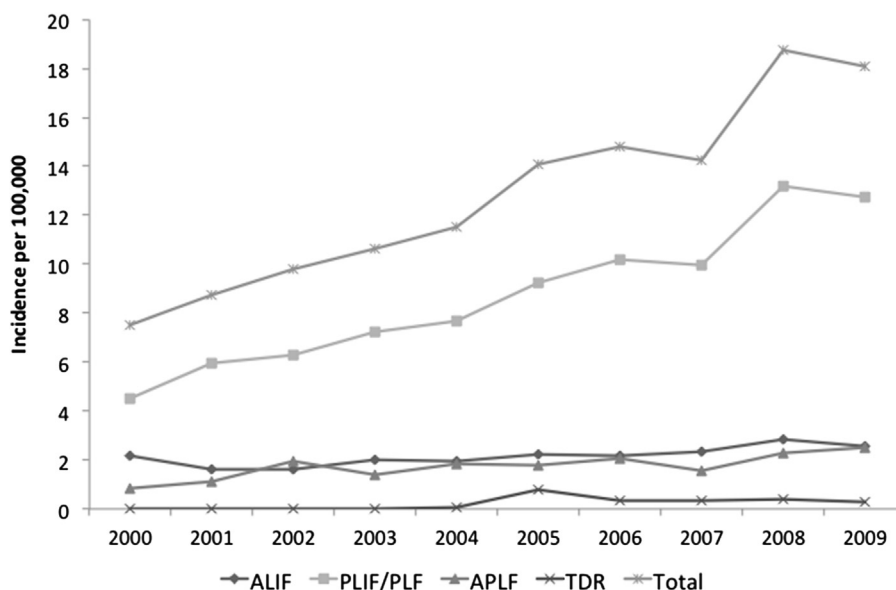


Fig. 2. Trends in the incidence of surgical treatment for lumbar degenerative disc disease from 2000 to 2009. TDR, total disc replacement; APLF, anterior and posterior lumbar fusion; PLIF, posterior lumbar interbody fusion; PLF, posterolateral lumbar fusion; ALIF, anterior lumbar interbody fusion.

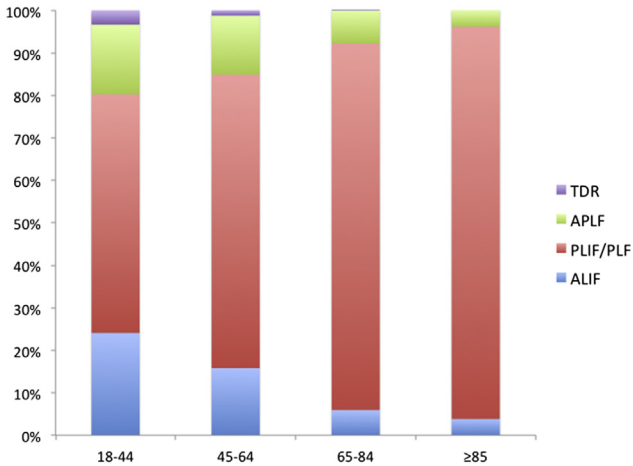


Fig. 3. Proportions of procedures in patients who underwent surgical treatment for lumbar degenerative disc disease stratified by age groups. TDR, total disc replacement; APLF, anterior and posterior lumbar fusion; PLIF, posterior lumbar interbody fusion; PLF, posterolateral lumbar fusion; ALIF, anterior lumbar interbody fusion.

incidence of patients with lumbar DDD who underwent surgical treatment increased over time: from 7.5 per 100,000 in 2000 to 18.1 per 100,000 in 2009 ($p < .001$) (Fig. 2). Population-adjusted incidence of patients with lumbar DDD who underwent ALIF, PLIF/PLF, and APLF increased over time: from 2.2 per 100,000 in 2000 to 2.6 per 100,000 in 2009 for ALIF ($p = .008$), from 4.5 to 12.7 for PLIF/PLF ($p < .001$), and from 0.8 to 2.5 for APLF ($p = .003$). Population-adjusted incidence of patients with lumbar DDD who underwent TDR remained stable over time: from 0.0 per 100,000 in 2004 to 0.3 per 100,000 in 2009 ($p = .975$).

In patients aged 18 to 44 years, ALIF was performed in 24.1% of patients, PLIF/PLF in 56.2%, APLF in 16.3%, and TDR in 3.4% (Fig. 3). In patients aged 45 to 64 years, ALIF

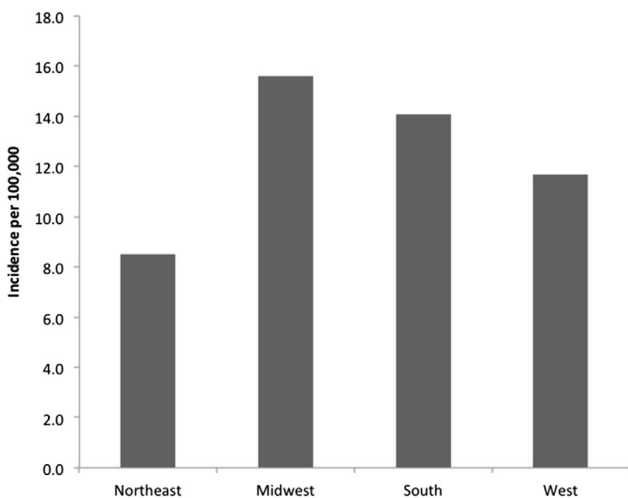


Fig. 4. Incidence of surgical treatment for lumbar degenerative disc disease between 2000 and 2009 stratified by hospital regions.

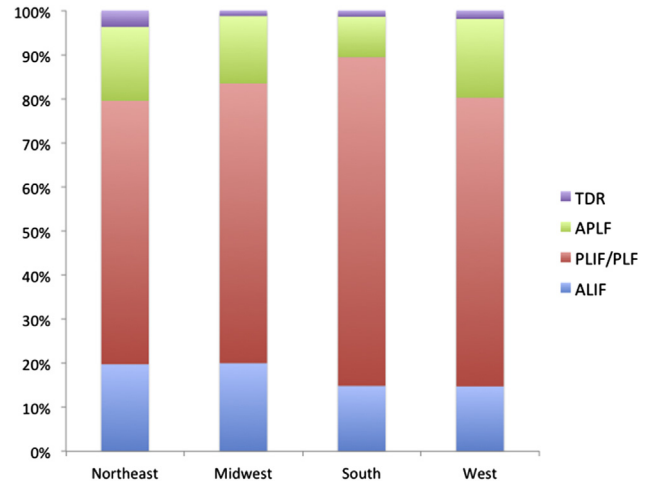


Fig. 5. Proportions of procedures in patients who underwent surgical treatment for lumbar degenerative disc disease stratified by hospital regions. TDR, total disc replacement; APLF, anterior and posterior lumbar fusion; PLIF, posterior lumbar interbody fusion; PLF, posterolateral lumbar fusion; ALIF, anterior lumbar interbody fusion.

was performed in 15.8% of patients, PLIF/PLF in 69.1%, APLF in 13.9%, and TDR in 1.3%. In patients aged 65 to 84 years, ALIF was performed in 5.9% of patients, PLIF/PLF in 86.3%, APLF in 7.7%, and TDR in 0.0%. In patients aged 85 years or older, ALIF was performed in 3.8% of patients, PLIF/PLF in 92.3%, APLF in 3.8%, and TDR in 0.0%.

Between 2000 and 2009, regional population-adjusted incidence of patients with lumbar DDD who underwent surgical treatment was 8.5 per 100,000 in the Northeast region, 15.6 in the Midwest region, 14.1 in the South region, and 11.7 in the West region (Fig. 4). In the Northeast region, ALIF was performed in 19.7% of patients, PLIF/PLF in 59.8%, APLF in 16.7%, and TDR in 3.7% (Fig. 5). In the Midwest region, ALIF was performed in 20.0% of patients, PLIF/PLF in 63.5%, APLF in 15.3%, and TDR in 1.3%. In the South region, ALIF was performed in 14.8% of patients, PLIF/PLF in 74.6%, APLF in 9.2%, and TDR in 1.4%. In the West region, ALIF was performed in 14.7% of patients, PLIF/PLF in 65.5%, APLF in 17.8%, and TDR in 1.9%.

Discussion

During the last decade, surgical treatment for lumbar DDD has increased 2.4-fold in the United States, although it is still controversial. Among the procedures, posterior approach procedures such as PLIF and PLF were most common and were performed in two-thirds of patients who underwent surgery for lumbar DDD. Posterior lumbar interbody fusion and PLF are familiar procedures in daily practice for spinal surgeons treating spinal diseases. In contrast, ALIF often necessitates dedicated anterior approach surgeons. However, among the procedures, APLF increased the most (3.0-fold). This may indicate increasing popularity of ALIF including XLIF/DLIF with percutaneous pedicle screw fixation during the last

decade. Extreme-lateral interbody fusion /DLIF can be performed without anterior approach surgeons.

Total disc replacement is another surgical option for the treatment of lumbar DDD that was approved in the mid-2000s [8]. However, contrary to our hypothesis, the advent of TDR did not change the overall trend of surgical treatment for lumbar DDD, although clinical trials and follow-up studies of the use of lumbar TDR have shown that TDR is not inferior when compared with the standard spinal fusion procedures [12–14]. Total disc replacement was performed in only 2.7% of patients with lumbar DDD who underwent surgical treatment between 2005 and 2009. In addition, there was no significant increase during that period. Awe et al. [14] reported that the frequency of lumbar TDR has decreased in a study using the NIS. The title of their article indicates “lumbar DDD;” however, they performed the analysis using subjects diagnosed with any disease. The reasons for poor adoption of TDR include the limited eligibility of patients, the lack of long-term clinical outcomes after TDR, the unfamiliarity of spinal surgeons, the absence of health insurance support, and the popularity of spinal fusion techniques [14].

Total disc replacement was more common in younger patients. Total disc replacement has multiple indication restrictions and older patients often do not meet the criteria for TDR. Posterior lumbar interbody fusion/PLF was more common in older patients and ALIF was more common in younger patients. We do not have a clear explanation for this; however, this may be related to the degree of complexity and the types of problems seen in younger patients [15].

Among the four regions in the NIS, surgical treatment for lumbar DDD was more common in the Midwest and South region. The incidence was 1.8 times higher in the Midwest region and 1.7-fold higher in the South region than in the Northeast region. Our results are consistent with previous findings. Previous database studies have reported higher rates of spinal fusion in the Midwest and South regions and that surgeons in the Northeast region were less likely to perform fusion surgery [15–20]. Weinstein et al. [16] mentioned that potential factors for regional discrepancies include lack of scientific evidence, financial incentives and disincentives to surgical intervention, differences in clinical training and professional opinion, and the introduction of new technology [16,21]. Previous studies have failed to detect systematic differences in patient preferences as the cause of variations in surgical rates and patient preferences are unlikely to explain the huge differences in rates observed across US regions [16,22,23]. Interestingly, trends in surgical procedures for lumbar DDD differed across regions. Total disc replacement was more common in the Northeast region. Posterior lumbar interbody fusion/PLF was more common in the South region, where the proportion was about three-quarters of the total. The regional variation in frequency of different types of surgery can be affected by age, smoking habits, and weight of patients in each region; however, it is difficult to show tables about comparison between the frequency of four procedures and

four regions after adjusting several factors because of many combinations. Despite this, our findings may indicate that the surgeons’ preference for the procedure was different in each region and may reflect differences in clinical training.

Our study is limited by several factors inherent to retrospective analysis of large administrative databases. Data entry may be subject to an element of coding or reporting bias; however, reporting should not vary substantially over time within the database. Our searches were done by primary diagnosis and did not account for patients with multiple diagnoses; however, if patients have other major spinal pathologies such as lumbar disc herniation, lumbar spinal stenosis, and acquired spondylolisthesis, those diagnoses should be the primary diagnosis rather than lumbar DDD. We could not differentiate surgical coding between TLIF and PLIF, as well as ALIF and XLIF/DLIF; therefore, TLIF and PLIF were grouped together and ALIF and XLIF/DLIF were grouped together. In addition, we could not find the ICD-CM-9 code for axial lumbar interbody fusion. Despite these limitations, these data give valuable information of trends in the surgical treatment for lumbar DDD in the United States during the last decade.

Conclusion

During the last decade, there was a significant increase in the surgical treatment for lumbar DDD. Although all fusion procedures significantly increased, TDR did not increase. Among the procedures, APLF increased the most, which may indicate the increased popularity of new surgical techniques such as percutaneous pedicle screw fixation and XLIF/DLIF. Surgical treatment for lumbar DDD was more common in the Midwest and South regions. Trends in the procedures were different depending on the age group and hospital region.

References

- [1] Madigan L, Vaccaro AR, Spector LR, Milam RA. Management of symptomatic lumbar degenerative disk disease. *J Am Acad Orthop Surg* 2009;17:102–11.
- [2] Knox BD, Chapman TM. Anterior lumbar interbody fusion for discogram concordant pain. *J Spinal Disord* 1993;6:242–4.
- [3] Carragee EJ, Lincoln T, Parmar VS, Alamin T. A gold standard evaluation of the “discogenic pain” diagnosis as determined by provocative discography. *Spine* 2006;31:2115–23.
- [4] Fritzell P, Hägg O, Wessberg P, Nordwall A, Swedish Lumbar Spine Study Group. 2001 Volvo Award Winner in Clinical Studies: lumbar fusion versus nonsurgical treatment for chronic low back pain. A multicenter randomized controlled trial from the Swedish Lumbar Spine Study Group. *Spine* 2001;26:2521–32.
- [5] Cain CM, Schleicher P, Gerlach R, Pflugmacher R, Scholz M, Kandziora F. A new stand-alone anterior lumbar interbody fusion device: biomechanical comparison with established fixation techniques. *Spine* 2005;30:2631–6.
- [6] Ozgur BM, Aryan HE, Pimenta L, Taylor WR. Extreme Lateral Interbody Fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. *Spine J* 2006;6:435–43.

- [7] Anderson DG, Sayadipour A, Shelby K, Albert TJ, Vaccaro AR, Weinstein MS. Anterior interbody arthrodesis with percutaneous posterior pedicle fixation for degenerative conditions of the lumbar spine. *Eur Spine J* 2011;20:1323–30.
- [8] Lin EL, Wang JC. Total disk arthroplasty. *J Am Acad Orthop Surg* 2006;14:705–14.
- [9] Healthcare Cost and Utilization Project (HCUP). Agency for Healthcare Research and Quality. Available at: <http://www.hcup-us.ahrq.gov/nisoverview.jsp>. Accessed December 1, 2013.
- [10] Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care* 1998;36:8–27.
- [11] U.S. Census Bureau. Population estimates: 2000s. Available at: <http://www.census.gov/popest/data/historical/2000s/index.html>. Accessed December 1, 2013.
- [12] van den Eerenbeemt KD, Ostelo RW, van Royen BJ, Peul WC, van Tulder MW. Total disc replacement surgery for symptomatic degenerative lumbar disc disease: a systematic review of the literature. *Eur Spine J* 2010;19:1262–80.
- [13] Jacobs WC, van der Gaag NA, Kruyt MC, Tuschel A, de Kleuver M, Peul WC, et al. Total disc replacement for chronic discogenic low back pain: a Cochrane review. *Spine* 2013;38:24–36.
- [14] Awe OO, Maltenfort MG, Prasad S, Harrop JS, Ratliff JK. Impact of total disc arthroplasty on the surgical management of lumbar degenerative disc disease: analysis of the Nationwide Inpatient Sample from 2000 to 2008. *Surg Neurol Int* 2011;2:139.
- [15] Pannell WC, Savin DD, Scott TP, Wang JC, Daubs MD. Trends in the surgical treatment of lumbar spine disease in the United States. *Spine J* 2013 Oct 31. <http://dx.doi.org/10.1016/j.spinee.2013.10.014>. pii: S1529-9430(13)01609-4. [Epub ahead of print].
- [16] Weinstein JN, Lurie JD, Olson PR, Bronner KK, Fisher ES. United States' trends and regional variations in lumbar spine surgery: 1992–2003. *Spine* 2006;31:2707–14.
- [17] Davis H. Increasing rates of cervical and lumbar spine surgery in the United States, 1979–1990. *Spine* 1994;19:1117–24.
- [18] Deyo R, Mirza S. Trends and variations in the use of spine surgery. *Clin Orthop Relat Res* 2006;443:139–46.
- [19] Taylor V, Deyo R, Cherkin D, Kreuter W. Low back pain hospitalization. Recent United States trends and regional variations. *Spine* 1994;19:1207–12.
- [20] Alesh H, Riley LH III, Skolasky RL. Insurance status, geography, race, and ethnicity as predictors of anterior cervical spine surgery rates and in-hospital mortality: an examination of United States trends from 1992 to 2005. *Spine* 2009;34:1956–62.
- [21] Deyo RA, Gray DT, Kreuter W, Mirza S, Martin BI. United States trends in lumbar fusion surgery for degenerative conditions. *Spine* 2005;30:1441–5; discussion 1446–7.
- [22] Hawker GA, Wright JG, Coyte PC, Williams JI, Harvey B, Glazier R, et al. Determining the need for hip and knee arthroplasty: the role of clinical severity and patients' preferences. *Med Care* 2001;39:206–16.
- [23] Smith DS, Krygiel J, Nease RF Jr, Sumner W 2nd, Catalona WJ. Patient preferences for outcomes associated with surgical management of prostate cancer. *J Urol* 2002;167:2117–22.