The association of regional intensity of neurosurgical care with spinal fusion surgery in the USA

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Abstract

Purpose There is wide regional variability in the volume of procedures performed for similar surgical patients throughout the USA. The purpose of this study was to investigate the association of spinal fusion operations with several socioeconomic factors.

Methods We performed a retrospective cohort study involving patients who underwent any neurosurgical procedure from 2005 to 2010 and were registered in National Inpatient Sample (NIS). A sub-cohort of patients undergoing spinal operations was also created. Regression techniques were used to investigate the association of the average intensity of neurosurgical care (defined as the average number of neurosurgical procedures per capita) with the average rate of fusions.

Results In the study period, there were 707,951 patients undergoing spinal procedures, who were registered in NIS. There were significant disparities in the fusion rate among different states (ANOVA, $P < 0.0001$), which ranged from 0.41 in Maine, where non-fusion surgeries were very predominant, to 0.62 in Virginia, where fusion was the main treatment modality used. In a multivariate analysis, the

intensity of neurosurgical care was associated with an increased fusion rate. A similar effect was observed for coverage by private insurance, higher income, urban hospitals, large hospital size, African American patients, and patients with less comorbidities. Hospital location in the northeast was associated with a lower rate in comparison to the midwest, and south. Coverage by Medicaid was associated with lower fusion rate.

Conclusions We observed significant disparities in the integration of fusion operations in spine surgery practices in the USA. Increased intensity of neurosurgical care was associated with a higher fusion rate.

Keywords Spinal fusion · Trends · Intensity of care · Diffusion of technology · NIS

Introduction

Over the last 30 years, there has been significant evidence that the rates and cost of spinal fusion have increased significantly in the USA [1]. A variety of factors may have contributed to this phenomenon, including improved biomechanical understanding of the human spine, advances in diagnostic imaging and device technology, as well as increased life expectancy of the population [1]. This trend is associated with a striking regional variation among individual hospital referral regions and states [2–6]. The observed geographic disparity in spinal fusions is similar to the various local practice patterns that have been documented for multiple surgical interventions [7–9]. The rates of procedures performed on similar patients are tremendously different for separate regions [7–9]. These disparities have been ascribed in part to race and other socioeconomic factors [10]. Prior research in

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cardiovascular disease [11] has demonstrated that the structural components of hospitals and particular surgeon characteristics may also explain this variation.

The intensity of neurosurgical care, as an indication of aggressiveness for intervention, may affect practice patterns, in particular with regard to more invasive procedures such as spinal fusions. Several regions demonstrate different intensity of neurosurgical care, reflecting local variations in resource utilization for similar patients. We hypothesize that these variations will correlate with the fusion rate performed in individual areas. The demonstration of such an association will partially explain the observed regional disparities in fusion rates. From a policy perspective, our study does not indicate whether it is possible to reduce overutilization and spending without affecting patient outcomes. However, if the USA as a whole could safely achieve intensity levels comparable to those of the lowest utilizing regions, significant savings could be achieved.

In the current study, using the National Inpatient Sample (NIS), we mapped the regional variations in the intensity of neurosurgical care and investigated their association with the utilization of spinal fusions. The NIS is an all-payer and age hospital discharge database that represents approximately 20 % of all inpatient admissions to nonfederal hospitals in the USA [12].

Methods

National Inpatient Sample (NIS) database

All patients undergoing neurosurgical interventions in the National Inpatient Sample (NIS) database [12] (Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality, Rockville, MD) between 2005 and 2010 were included in the analysis. For these years, the NIS contains discharge data from a stratified random sample of nonfederal hospitals (non-Veterans Affairs hospitals, but including both for-profit and not-for-profit hospitals). Overall, a representative 20 % subsample of all nonfederal US hospital discharges was collected. The database allows the production of national estimates using discharge-level weights. More information about the NIS is available at <http://www.ahrq.gov/data/hcup/nisintro.htm>.

Cohort definition

To establish the cohort of patients, we used ICD-9-CM codes to identify patients in the registry who underwent any neurosurgical procedure between 2005 and 2010 (Supplemental Table). In addition, we specifically identified patients undergoing spinal operations with and without

fusion (Supplemental Table). Incomplete data were available from AL, AK, DE, ID, MS, MT, NM, ND, PA, VT, and WY and those states were excluded.

Outcome variables

We created two primary outcome variables: the average intensity of neurosurgical care per state per year and the average rate of fusion surgeries to total spine surgeries per state per year. Average intensity of care was defined as the average number of neurosurgical procedures performed per capita over a year in a state. National estimates on the number of procedures were created using discharge-level weights provided by the NIS. The population of each state was calculated based on the 2010 US census data. Secondary outcomes were the rate of fusion surgeries to total spine surgeries per year for a diagnosis of spondylolisthesis (ICD-9-CM code 756.12), spinal fracture (ICD-9-CM code 733.1, 733.10, 733.13, 733.8, 733.81, 733.82, 805-806.9, 839-839.59), and degenerative scoliosis (ICD-9-CM code 737.30, or 737.39).

Exposure variables

The effect on the outcomes of the pertinent exposure variables was examined in a multivariate analysis. Age was a continuous variable. The number of orthopedic surgeons per capita and the number of neurosurgeons per capita were calculated based on data from the American Medical Association (AMA). They were then organized into quartiles with the lowest quartile being the reference value.

Gender, race (African American, Hispanic, Asian, or other, with Caucasian being the reference value), insurance (private insurance, self-pay, or Medicaid, with Medicare being the reference value), income, average intensity of neurosurgical care, and modified Charlson Comorbidity Index (CCI) [13, 14] were categorical variables. Income was defined as the median income based on zip code and was divided into quartiles, with the lowest quartile being the reference value. Average intensity of neurosurgical care, when used as an exposure variable, was divided into quartiles, with the lowest quartile being the reference value.

The hospital characteristics, used in the analysis as categorical variables, included hospital region (west, south, or midwest, with northeast being the reference value), hospital location (urban teaching or urban non-teaching, with rural being the reference value), and hospital bed size (medium or large, with small being the reference value). More information of the definitions of the various categories of hospital characteristics can be found at http://www.hcup-us.ahrq.gov/db/vars/nis_stratum/nisnote.jsp.

Statistical analysis

Linear regression analysis was used to compare the effect of the exposure variables on the primary outcomes. One-way ANOVA was used to compare differences in the outcome variables among the individual states. States with inadequate data on intensity and fusion were not included in the analysis. Linear regression analysis, adjusting for the effect of age, CCI, race, region, location, bed size, and teaching status of the hospital, was used to compare the association of different insurance coverage on the secondary outcomes.

For the purpose of sensitivity analysis, we performed a logistic regression to determine the effect of the exposure variables on the possibility of spinal fusion (not the fusion rate as used in the linear regression). This yielded similar results in terms of significant variables and therefore is not reported.

All probability values are the results of two-sided tests, and the level of significance was set at $P < 0.05$. Statistical analyses were performed using the XLSTAT version 2011.6.09 (Addinsoft) and SPSS Statistics version 20 (IBM, Armonk, NY).

Results

Regional variation in intensity of neurosurgical care

The intensity of neurosurgical care varied widely at the state level. There were significant disparities in the aggressiveness of neurosurgical intervention among different states (ANOVA, $P < 0.0001$). In a multivariate analysis higher intensity was associated with lower CCI (β 4.5, 95 % CI 3.0–8.7), more neurosurgeons per capita (β 0.75, 95 % CI 0.72–0.78), and large hospital size (β 0.29, 95 % CI 0.24–0.34). Blacks (β –0.15, 95 % CI –0.19 to –0.10), Hispanics (β –0.23, 95 % CI –0.27 to –0.19), Asians (β –0.28, 95 % CI –0.35 to –0.21), and coverage by Medicaid (β –5.40, 95 % CI –8.90 to –1.90) were associated with lower intensity. All the numbers reported have been normalized to a population of 100,000 subjects.

Demographics and clinical characteristics of the spine cohort

In the study period there were 707,951 patients (Fig. 1) undergoing spine surgery (mean age was 54.4 years, with 49.7 % females), who were registered in NIS, of whom 69,412 were treated in areas of the highest intensity and 22,806 were treated in areas of the lowest intensity (Table 1). Coverage by Medicare and Medicaid insurance, as well as patients of Hispanic and Asian races, was most

frequent in areas of the lowest intensity. Higher rates of private insurance and residence in the south were more common in areas of highest intensity. Among all patients examined, 372,338 underwent fusion operations, and 335,613 had non-fusion spinal procedures.

Regional variation in the fusion rate

The fusion rate varied significantly among several states (ANOVA, $P < 0.0001$). It ranged from 0.41 in Maine, where non-fusion surgeries were very predominant, to 0.62 in Virginia where fusions were the main spinal operation performed (Fig. 2). In a multivariate analysis (Fig. 3), private insurance (β 2.37, 95 % CI 2.10–2.64), higher income (β 2.46, 95 % CI 2.16–2.75), African American patients (β 2.87, 95 % CI 2.49–3.24), and patients with less comorbidities (β 1.38, 95 % CI 1.02–1.74) were associated with a higher fusion rate. Higher average intensity of neurosurgical care (β 40.7, 95 % CI 40.1–41.4) was associated with a higher fusion rate. Hospital location in the northeast was associated with a lower rate in comparison to the midwest, and the south. No consistent association was observed between the average fusion rate and the number of per capita neurosurgeons, whereas there was a negative association with the number of per capita orthopedic surgeons. All the numbers reported have been normalized to a population of 1,000 subjects.

Secondary outcomes

In a multivariate analysis controlling for all the covariates, private insurance (β 4, 95 % CI 3–6) was associated with a higher rate of fusion for patients undergoing surgery for degenerative spondylolisthesis. The opposite was true for

Fig. 1 Cohort selection for the study

Table 1 Demographics

	Top (4th)-intensity quartile patients		Low (1st)-intensity quartile patients		<i>P</i> value
	<i>n</i>	Percentage	<i>n</i>	Percentage	
Sample size	69,412		22,806		<0.0001
Age	53.27	16.63 (SD)	56.51	16.74 (SD)	
Sex					
F	34,082	49.10	11,132	48.81	0.448
M	35,326	50.90	11,674	51.19	0.439
Unreported data	4		0		
Quartiles of median income based on zip code					
1st Quartile	15,540	22.79	4,509	20.36	<0.0001
2nd Quartile	20,027	29.37	7,225	32.63	<0.0001
3rd Quartile	19,597	28.75	5,948	26.86	<0.0001
4th Quartile	13,015	19.09	4,461	20.15	0.007
Unreported data	1,233		663		
Payer					
Medicare	19,268	28.10	8,513	37.35	<0.0001
Medicaid	4,104	5.98	1,794	7.87	<0.0001
Private payer	36,486	53.21	9,846	43.20	<0.0001
Self-payer	1,251	1.82	210	0.92	<0.0001
Other	7,465	10.89	2,431	10.66	0.687
Unreported data	838		12		
Charlson Index					
Low (0–3)	65,856	94.88	21,190	92.91	<0.0001
Moderate/High (≥ 4)	3,556	5.12	1,616	7.09	<0.0001
Race					
Caucasian	29,810	86.81	17,620	85.84	<0.0001
African American	1,082	3.16	517	2.52	<0.0001
Hispanic	484	1.41	1,321	6.44	<0.0001
Asian	186	0.54	475	2.31	<0.0001
Other	2,776	8.08	594	2.89	<0.0001
Unreported cases	35,074		2,279		
Region					
Northeast	5,886	8.48	1,702	7.46	<0.0001
Midwest	26,942	38.82	9,896	43.39	<0.0001
South	20,247	29.16	0	0	<0.0001
West	16,337	23.54	11,208	49.15	<0.0001
Location					
Rural	5,401	7.78	1,366	5.99	<0.0001
Urban nonteaching	21,840	31.46	9,646	42.30	<0.0001
Urban teaching	42,171	60.76	11,794	51.71	<0.0001
Bedsizes					
Small	13,396	19.30	2,882	12.64	<0.0001
Medium	8,774	12.64	4,815	21.11	<0.0001
Large	47,242	68.06	15,109	66.25	<0.0001

patients covered by Medicaid ($\beta -5$, 95 % CI -9 to -2). Among patients undergoing treatment for spinal fractures, the rate of fusion was also higher for the privately insured ($\beta 2$, 95 % CI $1-3$) and lower for those covered by

Medicaid ($\beta -1$, 95 % CI -3 to 0.7). The same trends were observed for patients undergoing treatment for scoliosis with the privately insured undergoing more spinal fusions ($\beta 3$, 95 % CI $1-5$). The reference group for all regressions

Fig. 2 Map of the USA demonstrating the average fusion rate from 2005 to 2010 in quintiles. States with inadequate data are represented in white. There was wide variation among the states (ANOVA, $P < 0.0001$)

Fig. 3 Multivariate analysis demonstrating the associations of the exposure variables on the average fusion rate per year per state. The corresponding forest plots are presented on the right

was patients covered with Medicare. All the numbers reported have been normalized to a population of 1,000 subjects.

Discussion

With the increasing application of accountable care models, a wide variation in medical practice has been documented, with most observers agreeing that improvements in compliance with well-established guidelines could lead to substantial improvements in health outcomes of lagging regions [15]. In this context, the diffusion of surgical interventions, such as spinal fusions, is multifactorial and of particular interest in understanding local practice patterns [16, 17]. The annual number of spinal fusions in the USA rose by 77 % from 1996 to 2001, in contrast to hip and knee arthroplasty, increasing by only 13 % in the same period of time [1]. The factors contributing to the integration of spinal fusions in spinal practices can be associated with particular patient, hospital, and physician characteristics [16, 17].

At the patient level, we demonstrated that increasing income was related to a higher fusion rate. This is in accordance with the observation that income can affect the demand of new and expensive procedures [16, 17]. In the same context, private insurance was associated with a higher fusion rate, in comparison to coverage by Medicare, for patients undergoing treatment for spondylolisthesis, spinal fracture, or degenerative scoliosis. There was no conclusive data on the effect of minority status. Fusions were favored for African-Americans, whereas Hispanics and Asians had a higher rate of non-fusion spinal operations. As expected, patients with less comorbidities were associated with more fusion surgeries, since surgeons would tend to avoid these interventions in higher-risk patients. Hospital-level factors also influenced the integration of fusion. Institutions located in the midwest, the west, and the south had a higher rate in comparison to the northeast. Large hospital size in urban locations was associated with a higher rate.

In the literature, physicians are categorized into groups such as early adopters and laggards [16, 17], and the focus is on individual “change agents” who can shift treatment

norms within hospitals. However, the integration of new procedures does not always involve evidence-based practices, as is the case with spinal fusions. Despite the cases of spondylolisthesis and spinal instability, where there are evidence favoring fusions, the data are still inconclusive for other indications [18–23]. The added value of instrumentation in fusions is still under investigation in the literature [1]. For physicians, education is an important variable considered by all empirical studies of diffusion. In the context of spinal fusion, the availability of appropriately trained physicians (neurosurgeons and orthopedic surgeons) and their dynamic interactions can certainly affect the prevalence of this treatment. Another widely recognized factor of diffusion is profitability, which in the present study manifests as a higher rate of fusion surgeries for the privately insured.

Sociologic factors, such as physician interactions, personality characteristics, and prevalence of particular practices in several areas can affect the widespread use of spinal fusions. To represent these factors, we introduced intensity of neurosurgical care as a new metric of general practice patterns in neurosurgery, which reflects the aggressiveness of operative intervention for all neurological pathologies. We observed a positive association of increasing intensity with the integration of spinal fusions at the state level after controlling for the number of providers per capita (neurosurgeons or orthopedic surgeons) in the area. The reasons behind this observation are multifaceted. Neurosurgeons practicing in areas of high intensity most likely aggressively seek new technologies, ways to expand their scope of practice, and increase their efficiency. In addition, the competition generated from the interaction with other high-volume physicians in these regions would urge spine surgeons (neurosurgeons and orthopedic surgeons) to integrate innovation into their practice and increase their volume of lucrative procedures, by adopting fusion techniques.

The present study has several limitations common to administrative databases. Indication bias and residual confounding could account for some of the observed associations. In addition, some coding inaccuracies will undoubtedly occur and can affect our estimates. This is no different from other studies involving the NIS. However, several reports have demonstrated that coding for spinal surgery has shown good (cervical [24]) and moderate (lumbar [25]) association with medical record review. The NIS during the years studied did not include hospitals from all states. The states not included in our analysis were evenly distributed in the USA and relatively sparsely populated. Although the hospitals included were still diverse with respect to size, region, and academic status, the generalizability of our findings is limited to the states studied. To estimate the number of procedures performed per state, we used the standard weights provided. Although these

calculations are not expected to be absolutely accurate, they are adequate for the stratification of intensity of care we used in this analysis. The measure of intensity of neurosurgical care we used, although imperfect, has been utilized before by other specialties in analyses correlating the aggressiveness of care with outcomes and technology integration [10, 26].

The NIS does not provide information on standardized outcomes of pain and disability as well as post-hospitalization and long-term data on these patients, which are important in assessing the success of spinal surgery. Although we were able to analyze different insurances, data on which patients were reimbursed by workmen's compensation were lacking. The latter was part of the "other" category of the insurance variable. The relationship of coverage by workmen's compensation and rate of fusion is an interesting question that warrants further investigation. Additionally, we lacked specific information on the specialty of the surgeons performing the procedures. However, the local effect of the aggressiveness of neurosurgeons in a region, as measured by the intensity of neurosurgical care, is expected to affect equally all spinal surgeons in an area.

Conclusions

Practice patterns vary widely throughout the USA for multiple surgical interventions. We observed significant disparities in the intensity of neurosurgical care in the USA. The integration of invasive treatments, such as spinal fusions, in association with the intensity of neurosurgical care is of particular importance. Increased intensity was positively associated with the diffusion of spinal fusions. The demonstration of such an association will allow the identification of system-level determinants of variation and will provide actionable information about the quality of specific health-care systems.

Conflict of interest None.

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