Journal of Clinical Neuroscience 24 (2016) 43–46

Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

journal homepage: www.elsevier.com/locate/jocn

Clinical Study

Provider volume and short-term outcomes following surgery for spinal metastases

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ARTICLE INFO

Article history:
Received 10 August 2015
Accepted 16 August 2015

Keywords:
Complications
Hospital volume
Nationwide Inpatient Sample
Outcomes
Provider volume
Spinal metastases
Surgeon volume

ABSTRACT

This study aimed to analyze the impact of surgeon and hospital volume on short-term outcomes following surgery for spinal metastases. Data from the Nationwide Inpatient Sample (NIS; 2003–2009) were extracted. Patients who underwent decompression and/or fusion for metastatic spinal tumors were identified via *International Classification of Diseases, Ninth Revision* codes. Surgeon and hospital volume were evaluated as a continuous variable. Multivariable logistic regression analyses were performed to calculate the adjusted odds ratios (OR) of in-hospital mortality, post-operative complication development, non-routine discharges, prolonged length of stay, and high hospital charges with increasing surgeon and hospital volume. In total 3,069 admissions were examined. The overall in-hospital mortality rate was 4.4% and in-hospital complication rate 29.7%; non-routine discharges occurred in 63.3% of patients. Increasing provider volume was not associated with lower odds of in-hospital mortality. However, increasing surgeon volume was associated with significantly lower odds of developing an in-hospital complication (OR 0.70; 95% confidence interval [CI], 0.58–0.85) and having a non-routine discharge (OR 0.76; 95% CI, 0.66–0.87). Increasing hospital volume was not associated with lower odds of developing a post-operative complication (OR 1.17; 95% CI, 1.00–1.37), but was associated with lower odds of having a non-routine discharge (OR 0.83; 95% CI, 0.73–0.95). Patients operated on by higher volume surgeons were less likely to have a prolonged length of stay (over 14 days); higher hospital volume was associated with increased odds of high hospital charges (over $295,511 USD). In this study utilizing the NIS administrative database, patients with metastatic spinal tumors treated by higher volume surgeons had significantly lower complication rates, were more likely to be discharged home following surgery, and were less likely to have a prolonged length of stay. Increasing hospital volume was associated with lower non-routine discharge rates, but with higher hospital charges. Better outcomes with higher volume surgeons may be a reflection of patient selection, and further research is needed to corroborate our findings.

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1. Introduction

The volume-outcome relationship (VOR) has been studied in numerous surgical specialties, including cardiovascular [1], oncological [2], and general surgery [3]. The impact of provider volume on outcomes after various neurosurgical procedures has also been subject to research, with results indicating that higher surgeon/hospital volumes are associated with superior outcomes [4–9]. Dasenbrock et al. examined the impact of provider volume on surgical outcomes for patients following surgery for lumbar stenosis; undergoing surgery by a high-volume surgeon was associated with fewer post-operative complications, but hospital volume made no significant impact [8].

Metastatic tumors are the most common neoplasm in the spine, and they develop in approximately 40% of all cancer patients [10]. The most common primary sites are lung, breast, gastrointestinal, and prostate; 5–10% of all patients with systemic cancer present with spinal cord compression [11]. Additionally, these tumors may cause significant bony destruction and spinal instability, often requiring surgical decompression and stabilization. Despite their prevalence, the VOR for patients undergoing surgery for spinal metastases is, to our knowledge, unknown. In this study, we examine the independent effects of surgeon and hospital volume

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http://dx.doi.org/10.1016/j.jocn.2015.08.008
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on in-hospital mortality, complication development, and non-routine discharge rates in patients with spinal metastases.

2. Methods

2.1. Data source

All data analyzed in the present study were obtained from the Healthcare Cost and Utilization Project Nationwide Inpatient Sample (NIS) databases for the years 2003–2009. The NIS is an inpatient care database and contains discharge data for over eight million hospital stays annually from more than 1,000 hospitals in the United States of America. It is a 20% sample of most non-federal hospitals, stratified by geographic region, location (urban *versus* rural), teaching status, and size [8].

2.2. Inclusion criteria

The *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) diagnostic codes 198.3, 198.4 and 198.5 were used to identify patients with a metastatic neuraxis tumor (n = 117,268). Patients were considered to have received spinal surgery only if a spinal decompression (procedural code 03.01, 03.09, 03.4, and 03.54) and/or fusion (81.00–81.08 and 81.61) was one of the first three coded procedures (n = 5,097), in accordance with previous spinal surgery studies utilizing the NIS [8,12].

2.3. Patient and hospital characteristics

Independent patient covariates including patient age, sex, race, comorbidities, and expected primary payer were obtained. Hospital variables such as teaching status, bed size, and location were also reviewed. Surgeons and hospitals are identified in the NIS database via unique identifier codes. These codes were utilized to quantify surgeon and hospital volume; patients without this code were excluded (n = 2,028) [8]. Primary tumor histology was determined using the following codes: lung (V10.11, 162), breast (V10.3, 174), renal (V1052, 1890), prostate (V10.46, 162), and other or unknown. Visceral metastases were determined by using the codes 197.0, 197.1, 197.2, 197.6, 197.7, 198.8, 198.0, 198.1, 198.2, 198.6, 198.7, and 198.8. Patients were classified as having myelopathy by using the codes 336.3, 336.8, and 336.9.

2.4. Outcomes

The three primary endpoints evaluated in this study were in-hospital mortality, development of at least one in-hospital complication, and having a non-routine discharge. In-hospital complications were identified by using ICD-9-CM codes and defined as any of the following: neurological complications (997.0–997.09), pulmonary complications (518.5–518.53), myocardial infarction (410.0–410.91), acute kidney injury (584.5–584.9), urinary tract infection (595.0, 595.9, 599.0), deep vein thrombosis (453.4–453.42, 453.8, 453.9) pulmonary embolism (415.22, 415.13, 415.19), surgical site complication (998.83, 998.32, 998.51, 998.59, 998.6), gastrointestinal complication (008.45, 560.1, 997.4), decubitus ulcer (707.01–09), and complications related to an orthopedic or neurologic implant (996.2, 996.40, 996.42, 996.47, 996.49, 996.63, 996.66, 996.67, 996.75, 996.78, 996.79) [8]. Non-routine discharges were defined as any discharge other than home.

Secondary outcome measures included length of stay (LOS) and total hospital charges. Prolonged LOS and high hospital charges were defined as values over the 75th percentile.

2.5. Statistical analysis

Descriptive statistics were conducted for demographic variables. Univariable regression analyses were performed to assess possible confounders, and afterwards all covariates with a p value <0.05 were included in a stepwise multivariable logistic regression model to analyze outcomes in the form of adjusted odds ratios (OR) and 95% confidence intervals (CI). Surgeon and hospital volumes were each analyzed as a continuous variable. Due to positive skewing of surgeon and hospital volume, a logarithmic transformation was done prior to data analysis.

All multivariable analyses were adjusted for patient and hospital characteristics, including patient age, sex, comorbidities, and hospital location, size, and teaching status. To analyze the independent effect of surgeon and hospital volumes, analyses of surgeon volume were done after controlling for hospital volume and *vice versa* for hospital volume. Statistical analyses were performed using STATA 12/SE (StataCorp, College Station, TX, USA). Statistical significance was set at $p \leqslant 0.01$.

3. Results

A total of 3,069 admissions were examined (Table 1). The mean age for all patients was 59.6 ± 13.7 years, and 58.1% of patients were males. The majority of patients (77.4%) were Caucasian and the most common primary payer was private insurance in 45.1%

Table 1
Demographics of all patients undergoing surgery for spinal metastases

Characteristic	Value
Patients	3,069
Age (mean ± SD)	59.6 ± 13.7
Male (%)	58.1
Race	
Caucasian (%)	77.4
Black (%)	10.9
Hispanic (%)	7.2
Asian or Pacific Islander (%)	1.8
Native American (%)	0.6
Other (%)	2.1
Number of chronic conditions[1]	5.5 ± 2.6
Primary tumor histology	
Lung (%)	3.7
Breast (%)	8.9
Renal (%)	12.5
Prostate (%)	13.0
Other/unknown (%)	61.9
Expected primary payer	
Medicare (%)	38.4
Medicaid (%)	9.4
Private insurance (%)	45.1
Self-pay (%)	3.4
No charge (%)	0.6
Other (%)	3.2
Hospital location	
Rural (%)	1.4
Urban (%)	98.6
Hospital teaching status	
Non-teaching (%)	25.9
Teaching (%)	74.1
Hospital bed size	
Small (%)	4.1
Medium (%)	19.3
Large (%)	76.6
Mortality (%)	4.4
Total hospital charges, USD (mean ± SD)	107,485 ± 94,013
Length of stay, days (mean ± SD)	11.5 ± 9.8

[1] Defined as a condition that lasts 12 months or longer and meets one or both of the following: (a) it places limitations on self-care, independent living, and social interactions; (b) it results in the need for ongoing intervention with medical products, services, and special equipment.
SD = standard deviation.

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