Age Is a Risk Factor for Postoperative Complications Following Excisional Laminectomy for Intradural Extramedullary Spinal Tumors

Kevin Phan, BS1,2, Khushdeep S. Vig, BA3, Yam Ting Ho, BS1, Awais K. Hussain, BA3, John Di Capua, MHS3, Jun S. Kim, MD3, Samuel J. W. White, BA3, Nathan J. Lee, BS3, Parth Kothari, MD3, and Samuel K. Cho, MD3

Abstract

Study Design: Retrospective analysis.

Objective: The incidence of intradural extramedullary (IDEM) spinal tumors is increasing. Excisional laminectomy for removal and decompression is the standard of care, but complications associated with patient age are unreported in the literature. Our objective is to identify if age is a risk factor for postoperative complications after excisional laminectomy of IDEM spinal tumors.

Methods: A retrospective analysis was performed on the 2011 to 2014 ACS-NSQIP (American College of Surgeons National Surgical Quality Improvement Program) database for patients undergoing excisional laminectomy of IDEM spinal tumors. Age groups were determined by interquartile analysis. Chi-squared tests, t tests, and multivariate logistic regression models were employed to identify independent risk factors. Institutional review board approval was not needed.

Results: A total of 1368 patients met the inclusion criteria for the study. Group 1 (age ≤44) contained 372 patients, group 2 (age 45-54) contained 314 patients, group 3 (age 55-66) contained 364 patients, and group 4 (age >66) contained 318 patients. The univariate analysis showed that mortality and unplanned readmission were highest among patients in group 4 (1.26%, P = .011, and 10.00%, P = .039, respectively). Postoperative wound complications were highest among patients in group 1 (2.15%, P = .009), and postoperative venous thromboembolism and cardiac complications were highest among patients in group 3 (4.4%, P = .007, and 1.10%, P = .032, respectively). Multivariate logistic regression revealed that elderly age was an independent risk factor for postoperative venous thromboembolism (group 3 vs group 1; odds ratio = 6.739, confidence interval = 1.522-29.831, P = .012).

Conclusions: This analysis revealed that increased age is an independent risk factor for postoperative venous thromboembolism in patients undergoing excisional laminectomy for IDEM spinal tumors.

Keywords

spinal tumor, IDEM, intradural extramedullary, laminectomy, age, complications, NSQIP, National Surgical Quality Improvement Program, venous thromboembolism

Introduction

Primary spinal tumors are rare and account for approximately 5% to 15% of all adult spinal tumors.1 Spinal tumors can be classified as either intradural (within the dural sac) or extradural (outside the dural sac); intradural intramedullary tumors exist within the spinal cord and extramedullary tumor exist outside the spinal cord.1,2 Intradural extramedullary (IDEM) tumors account for 30% of all spinal tumors3,4 of which

1 Prince of Wales Private Hospital, Sydney, New South Wales, Australia
2 University of New South Wales, Sydney, New South Wales, Australia
3 Icahn School of Medicine at Mount Sinai, New York, NY, USA

Corresponding Author:
Samuel K. Cho, Department of Orthopaedics Surgery, Icahn School of Medicine at Mount Sinai, 5 East 98th Street, Box 1188, New York, NY 10029, USA.
Email: samuel.cho@mountsinai.org
majority are benign.\textsuperscript{5,6} The most common IDEM tumors are schwannoma (30\%) and meningioma (25\%).\textsuperscript{7,9} The incidence of benign primary spinal tumor is 0.76 per 100 000 (age adjusted) in the United States, benign primary spinal tumors are more common in females (60\%) than in males (40\%), and non-Hispanic races account for 90\% of benign cases.\textsuperscript{10} The incidence of tumor increases with age and peaks at an incidence of 2.53 per 100 000 at the age of 70 to 79 years.\textsuperscript{5,10,11}

Patients with spinal neoplasms commonly present with back pain, motor deficits, and sensory deficits due to physical compression of the tumor.\textsuperscript{6} Decompression and tumor resection are viewed as an appropriate option for IDEM tumors,\textsuperscript{5,12-14} and both can be achieved with excisional laminectomy.\textsuperscript{1,15} Studies have shown that tumor resection can improve general health, quality of living, pain, disability, and in some cases survival.\textsuperscript{8,16-20} However, surgery for spinal tumors is often complicated, costly, and associated with multiple complications and high mortality.\textsuperscript{13,21,22} It is therefore important to study the predictors and risk factors that affect the clinical outcomes and success of such operations. Prior studies have suggested factors such as patient comorbidities, tumor size and location, and surgeon-related factors can affect postoperative complications.\textsuperscript{16-20,23-26} However, there are currently no studies that have investigated the relationship between elderly age and the clinical outcome of excisional laminectomy for IDEM spinal tumors.\textsuperscript{27,28}

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database has accumulated data from over 500 medical centers in the United States, with information concerning the patients’ preoperative, intraoperative, and 30-day postoperative outcomes; it has also collected past clinical outcomes following operations for elective spinal surgeries including fusion for degenerative spinal diseases and spinal deformity.\textsuperscript{29-39} The use of the ACS-NSQIP database has helped improve the quality of clinical management, and this is seen with reduction in surgical site infection (SSI) and mortality rates in the Veteran Affairs system.\textsuperscript{39-41} This study aims to use the NSQIP database to help determine whether age can be a predictor for the clinical outcome of IDEM tumor resection via excisional laminectomy. The authors hope to improve clinical management by identifying which acute postoperative complications elderly patients are at risk for, which may help postoperative management and improve patient selection for spinal operations.

**Methods**

**Data Source**

This was a retrospective analysis of prospectively collected data from the NSQIP database between 2011 and 2014. ACS-NSQIP is a large national database with risk-adjusted 30-day postoperative morbidity and mortality outcomes. Over 500 hospitals that vary in size, socioeconomic location, and academic affiliation contributed data to the 2010 to 2014 ACS-NSQIP database.\textsuperscript{42} The data is collected by dedicated staff at each participating institution and includes data on over 150 demographic, preoperative, intraoperative, and early postoperative variables.\textsuperscript{42}

**Inclusion and Exclusion Criteria**

The ACS-NSQIP database from 2010 to 2014 was used in this study. Adult patients (≥18 years) undergoing laminectomy and excision of thoracic intradural and cervical intradural tumors were identified from the database. Cases with missing preoperative data; emergency cases; patients with a wound class of 2, 3, or 4; an open wound on their body; current sepsis; current pneumonia; prior surgeries within 30 days; and cases requiring cardiopulmonary resuscitation prior to surgery were excluded in order to reduce the risk of confounding variables. The patient population was divided into age quartiles: ≤44 years, 45 to 54 years, 55 to 66 years, and >66 years.

**Variable Definition**

Patient demographic variables included sex and race (white, black, Hispanic, and other). Other race included American Indian, Alaska Native, Asian, Native Hawaiian, Pacific Islander, or unknown/not reported. Preoperative variables included obesity (≥30 kg/m\(^2\)), diabetes (non–insulin-dependent diabetes mellitus or insulin-dependent diabetes mellitus), current smoking (within 1 year of surgery), dyspnea (≤30 days prior to surgery), functional status prior to surgery (independent or partially/relatively independent, <30 days prior to surgery), pulmonary comorbidity (ventilator dependent ≤48 hours prior to surgery or history of chronic obstructive pulmonary disease ≤30 days prior to surgery), cardiac comorbidity (use of hypertensive medication or history of chronic heart failure ≤30 days prior to surgery), renal comorbidity (acute renal failure ≤24 hours prior to surgery or dialysis treatment ≤2 weeks prior to surgery), steroid use for chronic condition (≤30 days prior to surgery), ≥10% loss of body weight (in the past 6 months), bleeding disorder (chronic, active condition), preoperative transfusion of ≥1 unit of whole/packed red blood cells (RBCs); ≤72 hours prior to surgery), and posterior fusion surgery.

Thirty-day postoperative outcome variables include mortality, wound complication (superficial or deep SSI, organ space infection, or wound dehiscence), pulmonary complication (pneumonia, unplanned reintubation, or duration of ventilator-assisted respiration ≥48 hours), venous thromboembolism (VTE; pulmonary embolism or deep vein thrombosis), renal complication (progressive renal insufficiency or acute renal failure), urinary tract infection, cardiac complication (cardiac arrest requiring cardiopulmonary resuscitation or myocardial infarction), intra-/postoperative RBC transfusion, reoperation (related to initial procedure), and unplanned readmission (related to initial procedure). Nonelective surgery unrelated to the procedure includes those where the patient was transferred from another acute care hospital to the hospital for surgery, transferred from an emergency clinic, undergoing emergent/urgent surgical case, or admitted to the hospital on
the day(s) prior to a scheduled procedure for any reason. ACS-NSQIP provides further information on variable characteristics.

**Statistical Analysis**

Univariate analysis was performed on patient demographics and preoperative, intraoperative, and postoperative characteristics using Pearson’s $\chi^2$ test. Fischer’s exact test was used where appropriate. Multivariable logistic regression models were employed, adjusting for patient demographics, preoperative characteristics, and patient comorbidities, to identify the influence of patient age on 30-day postoperative outcomes. The C-statistic, which is the area under the receiver operating characteristic curve, was also retrieved from the multivariate logistic regression model. The area under the receiver operating characteristic curve is a graph of the fallout rate (1 – specificity) against the sensitivity (true-positive rate). The area under this curve measures the ability of the model to correctly classify those with complication and those without complication. SAS Studio Version 3.4 (SAS Institute Inc, Cary, NC) was used for all statistical analysis.

**Results**

**Study Population**

A total of 1368 patients were included in this study, with an age range from 19 to 89 years. Patients were grouped into 1 of the 4 age groups: quartile 1 ($\leq$44 years) with 372 (27.2%) patients, quartile 2 (45-54 years) with 314 (23%) patients, quartile 3 (55-66 years) with 364 (26.6%) patients, and quartile 4 (>66 years) with 318 (23.3%) patients. Univariate analysis between the age cohorts with regard to patient demographics and preoperative and intraoperative variable showed significant differences in distribution of race ($P < .001$), diabetes ($P < .001$), pulmonary comorbidity ($P < .001$), cardiac comorbidity ($P < .001$), dyspnea ($P = .03$), and American Society of Anesthesiologists (ASA) class $\geq$3 ($P < .01$). There were no significant differences in proportion of patients with partially or totally dependent functional status between the age quartiles ($P = .13$). Compared with the young age group, the elderly group was more likely to be white and female (Table 1).

**Univariate Analysis**

Among the different 30-day postoperative clinical outcomes, we observed significant differences in mortality, wound complication, VTE, cardiac complication, and unplanned readmission between the 4 cohorts. Mortality rate was higher among the elderly patients (quartile 1 = 0%, quartile 2 = 0%, quartile 3 = 1.1%, quartile 4 = 1.3%; $P = .01$). Similarly, cardiac complication was also more prominent in the elderly group (quartile 1 = 0%, quartile 2 = 0%, quartile 3 = 1.1%, quartile 4 = 0.6%; $P = .03$), as well as unplanned readmission (quartile 1 = 0%, quartile 2 = 9.7%, quartile 3 = 3.6%, quartile 4 = 10%; $P = .04$). VTE was highest in quartile 3, and a significant difference is seen between cohorts as well (quartile 1 = 1.6%, quartile 2 = 0.6%, quartile 3 = 4.4%, quartile 4 = 1.9%; $P = .01$). With regard to wound complication, both elderly and young age group showed an equal rate (quartile 1 = 2.2%, quartile 2 = 0.6%, quartile 3 = 1.7%, quartile 4 = 0%; $P = .01$). No significant differences were found between the age cohorts for the following postoperative outcomes: length of stay ($P = .08$), pulmonary complication ($P = .66$), urinary tract infection ($P = .18$), intra-/postoperative RBC transfusion ($P = .47$), sepsis ($P = .2$), and reoperation related to initial procedure ($P = .78$; Table 2).

---

**Table 1. Univariate Analysis of Patient Demographics and Preoperative and Intraoperative Variables Between Age Cohorts (N = 1368).**

| Category                  | $\leq$ 44 Years, n (%) | 45-54 Years, n (%) | 55-66 Years, n (%) | >66 Years, n (%) | $P$  |
|---------------------------|-------------------------|--------------------|--------------------|------------------|------|
| Total                     | 372 (27.2)              | 314 (23.0)         | 364 (26.6)         | 318 (23.3)       |      |
| Sex                       |                         |                    |                    |                  |      |
| Female                    | 180 (48.4)              | 156 (49.7)         | 208 (57.1)         | 198 (62.3)       | .001 |
| Male                      | 192 (51.6)              | 158 (50.3)         | 156 (42.9)         | 120 (37.7)       |      |
| Race                      |                         |                    |                    |                  |      |
| White                     | 256 (69.2)              | 250 (80.7)         | 300 (82.4)         | 268 (84.3)       | .001 |
| Other                     | 30 (8.1)                | 16 (5.2)           | 18 (5.0)           | 6 (1.9)          |      |
| Black                     | 36 (9.7)                | 12 (3.9)           | 18 (5.0)           | 14 (4.4)         |      |
| Hispanic                  | 48 (13.0)               | 32 (10.3)          | 28 (7.7)           | 30 (9.4)         |      |
| Diabetes                  | 8 (2.2)                 | 24 (7.6)           | 50 (13.7)          | 64 (20.1)        | .001 |
| Dyspnea                   | 8 (2.2)                 | 8 (2.6)            | 18 (5.0)           | 18 (5.7)         | .03  |
| Functional status         |                         |                    |                    |                  |      |
| Independent               | 348 (93.6)              | 296 (94.3)         | 348 (95.6)         | 290 (91.2)       | .13  |
| Partially or totally      | 24 (6.5)                | 18 (5.7)           | 16 (4.4)           | 28 (8.8)         |      |
| dependent                 |                         |                    |                    |                  |      |
| Pulmonary comorbidity     | 2 (0.5)                 | 2 (0.6)            | 10 (2.8)           | 16 (5.0)         | <.001|
| Cardiac comorbidity       | 36 (9.7)                | 86 (27.4)          | 186 (51.1)         | 218 (68.6)       | <.001|
| Renal comorbidity         | 2 (0.5)                 | 0 (0.0)            | 0 (0.0)            | 0 (0.0)          | .16  |
| ASA class $\geq$3         | 100 (26.9)              | 126 (40.1)         | 188 (51.7)         | 238 (74.8)       | <.001|

Abbreviation: ASA, American Society of Anesthesiologists.
Multivariate Analysis

After adjustment for confounders, multivariate analysis demonstrated that the third age quartile (55-56 years) had a significantly increased odds of VTE compared with the first quartile (age ≤44 years; odds ratio = 2.66, 95% confidence interval = 1.01-7.03, \( P = .048 \); Table 3). There were no differences between the age quartiles in terms of proportion of patients with other complications after confounder adjustment.

Discussion

With increasing age of the growing elderly population in the West,\textsuperscript{27,28} patients often are frailer, have poorer physiological reserve, and are more susceptible to perioperative complications and poorer follow-up outcomes.\textsuperscript{43,44} Although spinal tumors are rare and IDEM tumors only account for 30% of all spinal tumors, an increasing fraction of this population fall into the elderly category.\textsuperscript{3,4} With the increase in age, there is a corresponding rise in spinal tumor incidence,\textsuperscript{5,10,11} and risk of postoperative complications.\textsuperscript{45} Therefore, there needs to be an emphasis on understanding how age can influence postoperative complications, which directly translates into increased financial burden, length of stay, and mortality rates.\textsuperscript{45} In our study, we analyzed 1368 patients and identified different 30-day postoperative complications the elderly patients were at risk for. Following multivariate adjustment, we identified that elderly patients had a greater risk for VTE complications. There were also no significant differences in other 30-day complications, despite the elderly patients having poorer preoperative comorbidities in terms of diabetes, dyspnea, ASA >3, pulmonary comorbidities, and cardiac comorbidities.

Cancer is a well-recognized risk factor for VTE given their prothrombotic and coagulopathic state.\textsuperscript{46} Yoshioka et al showed that patients with spinal tumors and existing neurological deficits such as paralysis are risk factors in developing VTE complications.\textsuperscript{47} Elderly age is another factor that resulted in a significant higher incidence of VTE.\textsuperscript{48,49} Schoenfeld et al in their retrospective analysis of 27,730 spine surgery patients demonstrated that body mass index >40 kg/m\textsuperscript{2} and ASA >3 were also independent risk factors for development of VTE.\textsuperscript{50} This association between age and VTE was also demonstrated for other spinal procedures, including anterior cervical discectomy and fusion.\textsuperscript{51} The influence of age on VTE incidence is likely exacerbated in oncological patients, given that cancer alone is another risk factor for VTE development, up to 20-fold.\textsuperscript{52} However, these trends have not been universal as Akeda et al did not find any significant correlation between risk of deep vein thrombosis with age or existing comorbidity in spinal tumor surgeries.\textsuperscript{22} This finding may be due to their underpowered analysis given that only 4 out of 14 individuals that showed VTE complications in this study were spinal tumor-related surgery.\textsuperscript{22}

Given the overall association between age and VTE complications particularly in IDEM spinal tumor patients, the suggested management includes the use of ultrasound for deep
venous thrombosis diagnosis, use of compression stockings, and prophylactic drugs in high-risk patients.\textsuperscript{22} In elderly patients, up to 10\% to 20\% of immediate death is due to VTE, and fatal pulmonary embolism is a preventable VTE consequence that accounts for 1\% of death of hospitalized patients.\textsuperscript{53,54} According to recommended guidelines, patient outcomes in our study would be considered high risk as they demonstrate high-risk factors such as age >60 years, acute chronic lung or inflammatory disease, decompensated heart failure, active cancer, and >40 years with a major surgery >45 minutes.\textsuperscript{53,54,57} Medical prophylactics for high-risk patients generally include low-dose unfractionated heparin, low-molecular-weight heparin (enoxaparin and dalteparin), and fondaparinux. With high-risk patients, the use of intermittent pneumatic compression over graduated compression stocking is viewed as a more effective mechanical prophylactic device.\textsuperscript{53,54,57} In addition, the risk of deep venous thrombosis without any prophylactic measures are 25\% for general surgery and 22\% for neurosurgery.\textsuperscript{53,54,57}

Patient preoperative morbidity as indicated by the ASA score may help explain why elderly patients (>55 years) were more likely to demonstrate a higher mortality rate and postoperative cardiac complications in univariate analysis of our data. Many of the patients in our study have an ASA score >3, and a higher ASA physical status class generally describes an individual who has more comorbidities, translating into longer hospital stay, higher postoperative mortality rate, and higher risk of myocardial injury.\textsuperscript{58} The ASA class is a moderate predictor for the physical status of a patient, but the interrater reliability disagreement was significantly less likely to occur for procedures such as neurosurgery and orthopedic surgery.\textsuperscript{58} In our study, differences in complication rates in elderly versus younger age quartiles were ameliorated following multivariate adjustment for confounders, suggesting that perioperative complications in the spinal tumor population is complex and multifactorial, and cannot be attributed to elderly age alone. Indeed, frailty indexes may be more representative of an elderly patient’s underlying comorbidities and physiological reserve, and has been shown to predict mortality and morbidity in older patients in spinal surgery.\textsuperscript{50,54} and cancer.\textsuperscript{59}

Few studies to date have assessed large nationwide databases or registries to determine risk factors for complications following intradural spinal tumors. Karhade et al\textsuperscript{60} performed an analysis of the NSQIP database to study patients undergoing spinal tumor surgery, and they evaluated 2207 patients with 36.4\% intradural tumor, 51.4\% extradural tumor, and 12.3\% intramedullary tumor. The authors found that the most common reason for readmission was wound infection/SSI (23.7\%) and VTE (12.7\%); they found the predictor for readmission was dyspnea, hypertension, extended hospital stay, and preoperative steroid use.\textsuperscript{60} In the present study, the rate of unplanned admission was higher in the elderly group (>55 years), and this group was also more likely to demonstrate dyspnea, hypertension, VTE, and wound infection complications in univariate analysis, but these differences became nonsignificant following multivariate adjustment.

Of interesting note was that aside from VTE, other perioperative complications including wound, pulmonary, renal, urinary tract, cardiac complications, transfusions, and unplanned readmissions were similar between the youngest age quartile and the oldest age quartile. This data suggests VTE is the main age-related complications in patients undergoing surgery for IDEM spinal tumors. As such, age alone should not be a contraindication to surgery in this population as the majority of perioperative morbidity and mortality outcomes are similar across the age quartiles. Our results support the notion that patient selection should focus on the underlying comorbidities of the patient rather than age alone. It is likely that patients who are with greater comorbidities are likely to have poorer outcomes following excisional laminectomy for IDEM tumors, but this remains to be formally investigated.

**Limitations**

The present study is constrained by several limitations. Patient cases were retrieved from the ACS-NSQIP database using Current Procedural Terminology (CPT) codes. This assumes that CPT codes were accurately recorded for each patient operation. The spinal procedure performed at each center may also be varied, and CPT codes do not account for this heterogeneity. Second, only 30-day perioperative outcomes were collected by ACS-NSQIP, and as such the presented results may not be applicable for long-term follow-up. Other relevant parameters including neurological outcomes, functional outcomes, intraoperative complications, tumor characteristic such as size and histology, as well as data on adjunctive chemotherapy or radiotherapy were not collected in this database, and as such could not be assessed in the present study. The NSQIP database is biased toward predominantly academic centers and may not be representative of results across the nation. Despite these limitations, analysis of the NSQIP database provides a large sample size and in-depth analysis of risk factors for perioperative complications following intradural spinal tumor surgery, which has not been well reported in the literature.

**Conclusions**

Using the ACS-NSQIP database to analyze IDEM spinal tumor excisional laminectomy, we demonstrated that elderly age to be independently associated with increased incidence of VTE but no difference in other perioperative complications. Our results suggest that elderly patients with an optimal risk profile should not be contraindicated from undergoing surgery for IDEM tumors. This data may help improve preoperative planning, optimization, and postoperative monitoring of patients undergoing excisional laminectomy for extramedullary spinal tumors.

**Declaration of Conflicting Interests**

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

**Funding**

The author(s) received no financial support for the research, authorship, and/or publication of this article.
References

1. el-Mahdy W, Kane PJ, Powell MP, Crockard HA. Spinal intradural tumours: part I—extramedullary. Br J Neurosurg. 1999;13:550-557.
2. Kane PJ, el-Mahdy W, Singh A, Powell MP, Crockard HA. Spinal intradural tumours: part II—intradural. Br J Neurosurg. 1999;13:558-563.
3. Van Goethem JW, van den Hauwe L, Ozsarlak O, De Schepper AM, Parizel PM. Spinal tumours. Eur J Radiol. 2004;50:159-176.
4. Traul DE, Shaffrey ME, Schiﬀ D. Part I: spinal-cord neoplasms-intradural neoplasms. Lancet Oncol. 2007;8:35-45.
5. Iacoangeli M, Gladi M, Di Rienzo A, et al. Minimally invasive surgery for benign intradural extramedullary spinal meningiomas: experience of a single institution in a cohort of elderly patients and review of the literature. Clin Interv Aging. 2012;7:557-564.
6. Yeo DK, Im SB, Park KW, Shin DS, Kim BT, Shin WH. Proﬁles of spinal cord tumors removed through a unilateral hemilaminectomy. J Korean Neurosurg Soc. 2011;50:195-200.
7. Helseth A, Mark SJ. Primary intraspinal neoplasms in Norway, 1955 to 1986. A population-based survey of 467 patients. J Neurosurg. 1989;71:842-845.
8. Zuckerman SL, Chotai S, Devin CJ, et al. Surgical resection of intradural extramedullary spinal tumours: patient reported outcomes and minimum clinically important difference. Spine (Phila Pa 1976). 2016;41:1925-1932.
9. Abul-Kasim K, Thurnher MM, McKeever P, Sundgren PC. Intradural spinal tumours: current classiﬁcation and MRI features. Neuroradiology. 2008;50:301-314.
10. Duong LM, McCarthy BJ, McLendon RE, et al. Descriptive epidemiology of malignant and nonmalignant primary spinal cord, spinal meninges, and cauda equina tumors, United States, 2004-2007. Cancer. 2012;118:4220-4227.
11. Morandi X, Haegelen C, Riffaud L, Amlashi S, Adn M, Brassier G. Results in the operative treatment of elderly patients with spinal meningiomas. Spine (Phila Pa 1976). 2004;29:2191-2194.
12. Joaquim AF, Almeida JP, Dos Santos MJ, Ghizoni E, de Oliveira E, Tedeschi H. Surgical management of intradural extramedullary tumors located anteriorly to the spinal cord. J Clin Neurosci. 2012;19:1150-1153.
13. Setzer M, Vatter H, Marquardt G, Seifert V, Vrionis FD. Management of spinal meningiomas: surgical results and a review of the literature. Neurosurg Focus. 2007;23:E14.
14. Sachdev S, Dodd RL, Chang SD, et al. Stereotactic radiosurgery yields long-term control for benign intradural, extramedullary spinal tumours. Neurosurgery. 2011;69:533-539.
15. Gottfried ON, Gluf W, Quinones-Hinojosa A, Kan P, Schmidt MH. Spinal meningiomas: surgical management and outcome. Neurosurg Focus. 2003;14:e2.
16. Adams H, Avendaño J, Raza SM, Gokaslan ZL, Jallo GI, Quinones-Hinojosa A. Prognostic factors and survival in primary malignant astrocytomas of the spinal cord: a population-based analysis from 1973 to 2007. Spine (Phila Pa 1976). 2012;37:E727-E735.
17. Bydon A, Xu R, Parker SL, et al. Recurrent back and leg pain and cyst reformation after surgical resection of spinal synovial cysts: systematic review of reported postoperative outcomes. Spine J. 2010;10:820-826.
18. Bydon M, De la Garza-Ramos R, Suk I, et al. Single-staged multi-level spondylectomy for en bloc resection of an epithelioid sarcoma with intradural extension in the cervical spine: technical case report. Oper Neurosurg. 2015;11:E585-E593.
19. Bydon M, Gokaslan ZL. Spinal meningioma resection. World Neurosurg. 2015;83:1032-1033.
20. Choy W, Lam SK, Smith ZA, Dahdaleh NS. Predictors of thirty day hospital readmission following posterior cervical fusion in 3401 patients [published online January 14, 2016]. Spine (Phila Pa 1976). doi:10.1097/BRS.0000000000001450.
21. Jacobs WB, Perrin RG. Evaluation and treatment of spinal metastases: an overview. Neurosurg Focus. 2001;11:e10.
22. Akeda K, Matsuhashi H, Imanishi T, et al. Prevalence and countermeasures for venous thromboembolic diseases associated with spinal surgery: a follow-up study of an institutional protocol in 209 patients. Spine (Phila Pa 1976). 2014;39:791-797.
23. Emel E, Abdallah A, Sofuoglu OE, et al. Long-term surgical outcomes of spinal schwannomas: retrospective analysis of 49 consecutive cases. Turk Neurosurg. 2017;27:217-225.
24. Lau D, Chan AK, Theologis AA, et al. Costs and readmission rates for the resection of primary and metastatic spinal tumors: a comparative analysis of 181 patients. J Neurosurg Spine. 2016;25:366-378.
25. Li C, Ye Y, Gu Y, Dong J. Minimally invasive resection of extradural dumbbell tumors of thoracic spine: surgical techniques and literature review. Eur Spine J. 2016;25:4108-4115.
26. Soleman J, Baumgarten P, Perrig WN, Fandino J, Fathi AR. Non-instrumented extradural lumbar spine surgery under low-dose acetylsalicylic acid: a comparative risk analysis study. Eur Spine J. 2016;25:732-739.
27. Rajaei SS, Bae HW, Kanim LE, Delamarter RB. Spinal fusion in the United States: analysis of trends from 1998 to 2008. Spine (Phila Pa 1976). 2012;37:67-76.
28. Cowan JA Jr, Dimick JB, Wainess R, Upchurch GR Jr, Chandler WF, La Marca F. Changes in the utilization of spinal fusion in the United States. Neurosurgery. 2006;59:15-20.
29. Di Capua J, Somani S, Kim JS, et al. Analysis of risk factors for major complications following elective posterior lumbar fusion. Spine (Phila Pa 1976). 2017;42:1347-1354.
30. Shin JI, Kothari P, Phan K, et al. Frailty index as a predictor of adverse postoperative outcomes in patients undergoing cervical spinal fusion. Spine (Phila Pa 1976). 2017;42:304-310.
31. Phan K, Kim JS, Lee NJ, et al. Frailty is associated with morbidity in adults undergoing elective anterior lumbar interbody fusion (ALIF) surgery. Spine J. 2017;17:538-544.
32. Phan K, Kim JS, Somani S, et al. Impact of age on 30-day complications after adult deformity surgery. Spine (Phila Pa 1976). 2018;43:120-126.
cervical discectomy and fusion (ACDF). *Spine (Phila Pa 1976).* 2017;42:456-464.

34. Phan K, Kothari P, Lee NJ, Virk S, Kim JS, Cho SK. Impact of obesity on outcomes in adults undergoing elective posterior cervical fusion. *Spine (Phila Pa 1976).* 2017;42:261-266.

35. Lee NJ, Kothari P, Phan K, et al. The incidence and risk factors for 30-day unplanned readmissions after elective lumbar fusion. *Spine (Phila Pa 1976).* 2018;43:41-48.

36. Phan K, Lee NJ, Kothari P, Kim JS, Cho SK. Risk factors for readmissions following anterior lumbar interbody fusion [published online May 9, 2016]. *Spine (Phila Pa 1976).* doi:10.1097/BRS.0000000000001677.

37. Lee NJ, Kothari P, Kim JS, et al. Nutritional status as an adjunct risk factor for early postoperative complications following posterior cervical fusion. *Spine (Phila Pa 1976).* 2017;42:1367-1374.

38. Phan K, Kim JS, Lee NJ, Kothari P, Cho SK. Relationship between ASA scores and 30-day readmissions in patients undergoing anterior cervical discectomy and fusion. *Spine (Phila Pa 1976).* 2017;42:85-91.

39. Molina CS, Thakore RV, Blumer A, Obremskey WT, Sethi MK. Use of the National Surgical Quality Improvement Program in orthopaedic surgery. *Clin Orthop Relat Res.* 2015;473:1574-1581.

40. Schoenfeld AJ, Carey PA, Cleveland AW 3rd, Bader JO, Bono CM. Patient factors, comorbidities, and surgical characteristics that increase mortality and complication risk after spinal arthrodesis: a prognostic study based on 5,887 patients. *Spine J.* 2013;13:1171-1179.

41. Aynardi M, Jacovides CL, Huang R, Mortazavi SM, Parvizi J. Risk factors for early mortality following modern total hip arthroplasty. *J Arthroplasty.* 2013;28:517-520.

42. Hall BL, Hamilton BH, Richards K, Bilimoria KY, Cohen ME, Ko CY. Does surgical quality improve in the American College of Surgeons National Surgical Quality Improvement Program: an evaluation of all participating hospitals. *Ann Surg.* 2009;250:363-376.

43. Parks RM, Rostoft S, Ommundsen N, Cheung KL. Peri-operative management of older adults with cancer—the roles of the surgeon and geriatrician. *Cancers (Basel).* 2015;7:1605-1621.

44. Fukuse T, Satoda N, Hijiya K, Fujinaga T. Importance of a comprehensive geriatric assessment in prediction of complications following thoracic surgery in elderly patients. *Chest.* 2005;127:886-891.

45. Patil CG, Patil TS, Lad SP, Boakye M. Complications and outcomes after spinal cord tumor resection in the United States from 1993 to 2002. *Spinal Cord.* 2008;46:375-379.

46. Bovill EG, van der Vliet A. Venous valvular stasis-associated hypoxia and thrombosis: what is the link? *Annu Rev Physiol.* 2011;73:527-545.

47. Yoshioka K, Murakami H, Demura S, et al. Comparative study of the prevalence of venous thromboembolism after elective spinal surgery. *Orthopedics.* 2013;36:e223-e228.

48. Imajo Y, Taguchi T, Yone K, et al. Japanese 2011 nationwide survey on complications from spine surgery. *J Orthop Sci.* 2015;20:38-54.

49. Hamel MB, Henderson WG, Khuri SF, Daley J. Surgical outcomes for patients aged 80 and older: morbidity and mortality from major noncardiac surgery. *J Am Geriatr Soc.* 2005;53:424-429.

50. Schoenfeld AJ, Herzog JP, Dunn JC, Bader JO, Belmont PJ Jr. Patient-based and surgical characteristics associated with the acute development of deep venous thrombosis and pulmonary embolism after spine surgery. *Spine (Phila Pa 1976).* 2013;38:1892-1898.

51. Buerba RA, Giles E, Webb ML, Fu MC, Gvozdyev B, Grauer JN. Increased risk of complications after anterior cervical discectomy and fusion in the elderly: an analysis of 6253 patients in the American College of Surgeons National Surgical Quality Improvement Program database. *Spine (Phila Pa 1976).* 2014;39:2062-2069.

52. Lee AY, Levine MN. Venous thromboembolism and cancer: risks and outcomes. *Circulation.* 2003;107(23 suppl 1):117-121.

53. Geerts WH, Pineo GF, Heit JA, et al. Prevention of venous thromboembolism: the Seventh ACCP Conference on Antithrombotic and Thrombolytic Therapy. *Chest.* 2004;126(3 suppl):338S-400S.

54. Cardiovascular Disease Educational and Research Trust; Cyprus Cardiovascular Disease Educational and Research Trust; European Venous Forum; International Surgical Thrombosis Forum; International Union of Angiology; Union Internationale de Phlébologie. Prevention and treatment of venous thromboembolism. International Consensus Statement (guidelines according to scientific evidence). *Int Angiol.* 2006;25:101-161.

55. Kammoun S, Gold G, Bouras C, et al. Immediate causes of death of demented and non-demented elderly. *Acta Neurol Scand Suppl.* 2000;176:96-99.

56. Attems J, Arbes S, Böhm G, Böhmer F, Lintner F. The clinical diagnostic accuracy rate regarding the immediate cause of death in a hospitalized geriatric population; an autopsy study of 1594 patients. *Wien Med Wochenschr.* 2004;154:159-162.

57. Ali MS, Czarnecka-Kujawa K. Venous thromboembolism in the elderly. *Curr Geriatr Rep.* 2016;5:132-139.

58. Sankar A, Johnson SR, Beattie WS, Tait G, Wijeyasundera DN. Reliability of the American Society of Anesthesiologists physical status scale in clinical practice. *Br J Anaesth.* 2014;113:424-432.

59. Lin HS, Watts JN, Peel NM, Hubbard RE. Frailty and postoperative outcomes in older surgical patients: a systematic review. *BMC Geriatr.* 2016;16:157.

60. Karhade AV, Vasudeva VS, Dasenbrock HH, et al. Thirty-day readmission and reoperation after surgery for spinal tumors: a National Surgical Quality Improvement Program analysis. *Neurosurg Focus.* 2016;41:E5.