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Effect of surgeon experience on surgical outcome of 80-year-old or older intracranial meningioma patients

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Key words: Elderly patients; intracranial meningioma; mortality; surgery; surgeon experience; surgeon volume

Abstract

Objective: Previous reports suggest that more experienced surgeons have better postoperative outcomes in neurosurgery. We studied whether this association is found in a fragile cohort of ≥80-year-old intracranial meningioma (IM) patients.

Methods: We identified 83 very old IM patients who were operated on by 12 different surgeons between 2010 and 2018. Besides general patient- and tumor-related characteristics, we collected information about the surgeons' case volume and length of surgical career (LSC). We classified neurosurgeons into three different categories: 1) low- (8 surgeons; 1–4 operations per surgeon), 2) moderate- (3 surgeons; 8–12 operations per surgeon) and 3) high-volume (1 reference surgeon; 37 operations) category. We calculated odds ratios (ORs) with 95% confidence intervals for one-year mortality and three-month independency (capability to live at home) by surgeon volume categories and per five-year increase of LSC.

Results: We found no significant differences in any preoperative characteristics between the surgeon volume categories. IM patients operated on by low-volume surgeons had the lowest risk of first-year mortality (OR=0.15 (0.01–2.05) and the highest likelihood of living at home after three months of surgery (OR=12.61 (1.21-131.03)). Increasing LSC associated with one-year mortality (OR=1.34 (1.03-1.73)) and with lower likelihood to live at home three months after surgery (OR=0.83 (0.69-1.00)), but these associations were slightly non-significant after adjusting for IM patients' age, sex and preoperative independency.

Conclusions: In a high-volume academic hospital, less experienced neurosurgeons seem to achieve similar results as the more experienced neurosurgeons even when operating on selected highly fragile meningioma patients.

Introduction

Surgeon volume associates with better postoperative outcomes in numerous surgical procedures[1, 2]. In neurosurgery, such association has been reported in tumor[3-6], vascular[7-9] and spine surgeries[10, 11]. This kind of evidence is often used to justify centralization of certain surgeries to more experienced surgeons.

According to a recent review[12] and report[13], surgical treatment of highly selected 80-years or older intracranial meningioma (IM) patients appears to be justified. However, since the overall complication and early mortality rates are still significant, we believe that investigating whether surgeons' experience impacts on the postoperative outcome should be best studied in this highly fragile patient group, especially since the number of very old IM patients will likely increase in the future. We hypothesized that the patients operated on by surgeons with a high case volume have less postoperative complications, shorter hospital stays, lower mortality rates and higher likelihoods of living at home after surgery.

Methods and materials

Ethical consideration. The local institutional review board of Helsinki University Hospital (HUH) approved our retrospective data collection and study design, and granted a waiver for acquiring the patient consent. In addition, we conducted the study in line with the Declaration of Helsinki[14].

Patient characteristics. We identified 83 consecutive IM patients who were operated on at the age of 80 years or more in the neurosurgical department of HUH (catchment area 2 million inhabitants) between 2010 and 2018. Through electronic medical record (EMR) systems, we collected information about demographics (age and sex) and preoperative performance status (Helsinki version of American Society of Anesthesiologist, Helsinki ASA scale[15], Karnofsky Performance Status, KPS[16]) and capability to live at home. We recorded the tumor size (maximum diameter), location and multiplicity based on the preoperative magnetic resonance images. The histology classification of tumors (WHO grade) was based on neuropathology reports. In addition, we collected data on recorded postoperative complications, surgery time (skin-to-skin in minutes), length of hospitalization (days) and surgeons' self-estimated extent of resection (partial/total).

Surgeons. Based on the EMR system, we identified 12 different surgeons who operated on at least one very old IM patient between 2010 and 2018. In our study unit, patients are referred to the department rather than a specific neurosurgeon; a surgeon is selected based on their subspecialty and level of training. This means that the patients' postoperative care is not only under the surgeon who performed the surgery, but also under all neurosurgeons and residents running the two neurosurgical departments. In the study hospital, the primary surgeon performs the approach and the tumor removal.

Of the 12 surgeons, we classified 8 as low-volume surgeons (1–4 patients per surgeon), 3 as moderate-volume surgeons (8–12 patients per surgeon), and 1 as high-volume surgeon (37 patients;

none of the authors). Patients operated on by the high-volume surgeon were used as a reference group (the benchmark surgeon) in the postoperative outcome analyses. In case of the surgeries performed by the benchmark surgeon, the dural suturing, bone flap re-implantation and skin closure were nearly always performed by a cerebrovascular fellow or by a recently graduated consultant neurosurgeon. Regarding the low- and moderate-volume surgeons, we went through the operative reports to identify whether a more experienced neurosurgeon was involved in the surgery. All low- and moderate-volume neurosurgeons had undergone a one-year vascular and skull base fellowship after their six-year residency program at HUH. We extracted data about surgeons' birth year from a nationwide open website (JulkiTerhikki). In addition, we estimated the length of the surgical career (LSC) of each primary surgeon by calculating the time difference between the operation year and the primary surgeon's year of specialization (openly available at https://www.hus.fi/en/medical-care/medical-services/Neurosurgery/for_professionals/staff/neurosurgeons/Pages/default.aspx). Since LSC depended on the year of operation, it was not constant for each surgeon but rather calculated separately for each operation.

Postoperative outcome. As primary postoperative outcome measures, we determined one-year mortality rate and IM patients' three-month independency (capability to live at home). We further determined one-month mortality and an overall postoperative complication rate including major (e.g., major intracranial bleeding, new hemiparesis, pulmonary embolism and pneumonia) and minor (e.g., wound, urinary tract and other minor infections, subjective visual or balance disturbances and dysphasia) complications[17].

Statistical analysis. We used the Kruskal-Wallis test to determine differences between the three volume categories. When applicable, we performed post hoc analysis with a Wilcoxon rank-sum test to define the differences between each category. We also used a Wilcoxon rank-sum test to determine the LSC differences between preoperatively dependent and independent patients, as well as between the patients with low (I-III) and high (IV-V) Helsinki ASA scores[15]. We used a linear regression model to evaluate the associations (estimates with 95% confidence intervals (CIs)) between every five-year increase of LSC, surgery time, and length of hospitalization. In addition, we used logistic regression analysis to calculate odds ratios (ORs) and 95% CIs for outcome variables between each volume category and per five-year increase of LSC at the time of operation. In addition to univariate model, we used the adjusted model including IM patients' age, sex and preoperative independency. All statistical analyses were performed by Stata version 14.2 (Stata Corp, College Station, TX).

Results

Surgeons. The majority (58%) of all surgeons were men; the median age at the time of operation was 54 years, and the median LSC at the time of operation was 21 years. In the high-volume category, the median LSC of the primary surgeon was substantially higher (34 years) than in the moderate- (8 years) and low-volume categories (4 years) ($p<0.001$). Only one patient was operated on by a neurosurgical resident two years before the end of the residency. The resident consulted a moderate-volume category neurosurgeon during the surgery, and the moderate-volume neurosurgeon eventually performed the tumor removal. In all other surgeries, the low- and moderate-volume surgeons performed the approach and the tumor removal by themselves.

Patient characteristics. Table 1 presents the patient characteristics by volume groups. Most patients in all categories were women. Despite the fact that the low-volume surgeons operated no 90-years or older IM patients (n=3), we found no significant difference in the median age of patients between volume categories (Table 1). Low-volume surgeons operated most often on IMs located in convexity as well as WHO grade II tumors, but the differences with other volume categories was non-significant. Other tumors characteristics, namely IM size, multiplicity and edema were similar between the volume categories. Patients operated on by low-volume surgeons had slightly (but non-significantly) lower (II-III) Helsinki ASA scores, and were slightly (but non-significantly) more often preoperatively independent (Table 1). Similarly, the median LSC was higher for surgeons who operated on preoperatively dependent (31 years) than independent patients (19 years). In addition, median LSC was higher for surgeons who operated on patients with high Helsinki ASA scores (26 years) than for surgeons operating on low Helsinki ASA score patients (20 years). However, both associations were non-significant ($p=0.97$ and $p=0.40$, respectively).

Operative characteristics. Surgery time of the benchmark surgeon was the shortest (p=0.13), but the difference in surgery time was evident only between moderate- and high-volume surgeons (p=0.04), where moderate-volume surgeons' surgery time was the longest (Table 2). The low-volume surgeons' surgery times did not differ from the benchmark surgeon (p=0.29). The median length of hospital stay was longer for patients operated on by the benchmark surgeon than by the low- (p=0.06) or moderate-volume (p=0.02) surgeons (Table 2). Each five-year increase in LSC was generally associated with 10.8 (4.2–17.4) minutes shorter (p=0.002) surgery time but 0.22 (-0.03–0.48) days longer length of stay (p=0.08). The inverse association between LSC and surgery time occurred in skull-based meningiomas (p=0.03), but not in the convexity meningiomas (p=0.14). We did not find significant volume- or LSC-based differences in the reported extent of resection.

Postoperative outcomes. The most commonly identified major complication in both low- (n=2) and moderate-volume categories (n=4) was a major intracranial bleeding (causing a mass effect and/or requiring surgery), whereas pneumonia was the most common major complication in the high-volume category. By surgeon-volume categories, the incidence of overall and major complications were similar (Table 3). We found that the patients operated on by low-volume surgeons had the lowest rate of one-year mortality (7%) and the highest percentage (93%) of patients living at home after surgery (Table 3). When assessing only patients who were independent before surgery, all patients operated on by low-volume surgeons were able to live at home three months after the surgery, and none of the patients died during the first postoperative year. Of the preoperatively independent patients, the percentage of patients living at home after three months was 76% for the moderate- and 71% for the high-volume surgeons, and the one-year mortality rates were 10% and 17%, respectively. In comparison to the benchmark surgeon, patients operated on by the low-volume surgeons had a lower risk of one-year mortality (OR=0.15 (0.01-2.05)) in an adjusted multivariable model that included IM patients' age, sex and capability to live at home before operation (Table 4). In addition, the probability of living at home three months after surgery was higher for the low-volume surgeons ((OR=12.61 (1.21-131.03). In the univariate model, LSC (per every five-year increase) was similarly associated with higher one-year mortality (OR=1.34 (1.03-1.64)) and lower likelihood to live at home three months after surgery (OR=0.83 (0.69-1.00)). However, in the multivariate model, the associations were slightly non-significant (Table 4). We found no significant associations between postoperative complications or 1-month mortality rates and surgeon volume categories or LSC (Table 4).

Discussion

We found that surgeons with less experience had comparable surgical outcomes to the more experienced neurosurgeons. Interestingly, the likelihood of living at home three months after surgery was highest for patients operated on by low-volume surgeons. After accounting for the patients' preoperative performance status, meningioma size and meningioma location, the results remained the same. Even though the surgery time – especially in skull-based meningiomas – shortened with the surgeons' experience, this did not reflect postoperative complication rates or length of hospital stay. Since many major complications, such as oculomotor paresis, postoperative hydrocephalus and cerebrospinal fluid leakage requiring a reoperation, were only reported in patients operated on by the high-volume surgeon, this may explain partly why the median length of hospitalization was longer and the probability to live at home after three months was lower in this patient group. Given that the study hospital is an international teaching center, and that all expect one operations were performed by an individual surgeon from opening to the tumor removal, these findings suggest that with experienced case selection and allocation processes, even less experienced neurosurgeons can achieve comparable surgical results, even when operating on highly fragile IM patients. Notably, however, only one out of 83 surgeries was allocated to a resident, and in this case, a more experienced neurosurgeon performed the tumor removal. Taken together, meningioma surgery of 80-year-old or older patients can perhaps be considered demanding, and not necessarily suitable for residents.

The negative results of our study should be interpreted with caution due to the low case number, which increases the likelihood of type 2 errors (false negative results). In fact, if the study population were ten times larger (n=830) with otherwise similar characteristics, patients operated on by the benchmark surgeon would have had lower preoperative KPS values ($p<0.001$) and higher Helsinki ASA scores ($p<0.001$), which are both commonly associated with a higher risk of unfavorable postoperative outcome[12]. In addition, tumors operated on by low-volume surgeons would have been located more commonly in convexity ($p<0.001$), which may partly explain why we did not find many significant differences between surgeon groups. In other words, it is possible that the benchmark surgeon operated on the patients with the highest risk for postoperative complications. Nevertheless, in the same scenario, patients operated on by low-volume surgeons would still live more commonly at home three months after surgery (adjusted OR=12.61 (6.02–26.44)), and the one-year mortality rate would be lower (adjusted OR=0.15 (0.07–0.35)). In addition, postoperative complication and short-term mortality rates would still not differ between the low- and high-volume surgeons.

A few specific aspects are worth noting. First, all surgeries were performed in a high-volume hospital, where postoperative care in the intensive care unit and bed wards may play an important role in harmonizing surgical outcome results, especially when the length of hospital stay is more than a few days. This has been suggested in previous studies[1, 2, 18]. Second, neurosurgical residents at HUH start to operate by themselves as primary surgeons in the very beginning of their residency under the supervision of a senior neurosurgeon, thus their number of previous craniotomies may be notably high, especially in comparison to many other centers. Moreover, all graduated neurosurgeons operate during a one year fellowship year together with the chairman of the department, and this may contribute to more harmonized surgical techniques[19] and perhaps to relatively harmonized outcome results. Third, in the study center, patients are treated by a rather large group of neurosurgeons without any difficulty of consulting other colleagues before, during and after surgery – the collective experience of the group is utilized with full transparency. Daily x-ray meetings and discussions also function as transparent mortality and morbidity meetings, and thus serve as additional internal quality controls. Fourth, numerous international surgeons have operated in the study hospital throughout the years, and most of the graduated neurosurgeons have spent time in international centers. Therefore, the study surgeons may have gained a wider and more international education than in some other centers. Last, although we did not find statistically significant differences between patient- or tumor-related factors, it is still more likely that the most experienced neurosurgeons have operated on the most challenging tumors. Since the closing procedure was not usually performed by the benchmark surgeon, this may have had an impact on the length of hospital stay, too.

Our study has several other limitations to consider. Due to the retrospective nature of the study setup, we may have missed non-routinely collected data on minor complications. Because of this, we focused more on the unambiguous measures such as survival rates and capability to live at home that were available for 100% of the patients. Moreover, since we did not have data on intraoperative bleeding, we were not able to investigate associations between excessive blood loss and postoperative outcomes. However, in our previous prospective study about complications in cranial neurosurgery, the blood loss of meningioma surgery was minimal in HUH[20]. As another limitation, we did not have information about the overall case volumes of each surgeon. Thus, low-volume neurosurgeons may actually have a lot of experience in meningioma resections of younger patients.

However, this likelihood is low in the study hospital, since surgeons' surgical profiles are based on lesions – not on the age of the patient. Moreover, the high-volume category included only one surgeon who performed almost half of the surgeries. Allowing only one or two neurosurgeons in a large department to perform all difficult surgeries without sharing with others may have its downside. Nevertheless, we believe that the most experienced surgeons are so-called benchmark surgeons in most surgical units in the world, also in the daily clinical practice. Therefore, our approach may not be so biased. In addition, to our knowledge, this is the first study focusing on the associations between surgeons' case-volumes, length of surgical careers and postoperative measures in a very old neurosurgical patient group. The number of individuals in this group will increase significantly in the near future in high-income countries. Hence, the presented findings of this study may serve as benchmarking results for future studies and for fellow neurosurgeons with various experience. Many times, only the results of highly experienced neurosurgeons are presented in the literature.

Conclusions

Based on our findings, neurosurgeons with low case-volumes and shorter surgical careers may achieve surgical results comparable to benchmarking surgeons when operating on selected very old IM patients in a high-volume academic hospital. The results also suggest that not only the number of surgeries as a primary surgeon but also the quality of early and continuous training may make a difference.

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Declarations of interest

None

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Tables

Table 1. Preoperative characteristics by surgeon-volume categories.

	Low volume (8 surgeons)	Moderate volume (3 surgeons)	High volume (1 surgeon)	p-value for difference
N of patients	15	31	37	
Age, median (range)	83 (80-87)	82 (80-96)	83 (80-93)	0.75
Sex, n (%)				0.40
• Men	5 (33)	7 (23)	14 (38)	
• Women	10 (67)	24 (77)	23 (62)	
Helsinki ASA scale, n (%)				0.13
• I	0 (0)	0 (0)	0 (0)	
• II	2 (13)	3 (10)	0 (0)	
• III	10 (67)	13 (42)	21 (57)	
• IV	3 (20)	15 (48)	16 (43)	
• V	0 (0)	0 (0)	0 (0)	
Preoperative KPS, median (IQR)	70 (50-80)	60 (40-70)	60 (40-70)	0.25
Preoperative independency, n (%)				0.56
• Independent	12 (80)	21 (68)	24 (65)	
• Dependent	3 (20)	10 (32)	13 (35)	
WHO grade of IM, n (%)				0.09
• I	7 (47)	22 (71)	23 (62)	
• II	7 (47)	6 (19)	6 (16)	
• III	0 (0)	0 (0)	0 (0)	
• Missing	1 (7)	3 (21)	8 (22)	
IM size, median (IQR)	4.2 (3.3-5.3)	4.6 (3.8-5.7)	4.3 (3.7-5.3)	0.70
IM edema, n (%)				0.11
• No	6 (40)	6 (19)	16 (43)	
• Moderate	8 (53)	18 (58)	15 (41)	
• Severe	1 (7)	7 (23)	6 (16)	
IM location, n (%)				0.28
• Convexity	8 (53)	9 (29)	14 (38)	
• Falx	2 (13)	4 (13)	3 (8)	
• Skull-base	4 (27)	15 (48)	14 (38)	
• Posterior fossa	1 (7)	2 (6)	4 (11)	
• Other	0 (0)	1 (3)	2 (5)	
Number IMs, n (%)				0.90
• One	14 (93)	28 (90)	33 (89)	
• Multiple	1 (7)	3 (10)	4 (11)	

ASA=American Society of Anesthesiologist; IM=intracranial meningioma; IQR=interquartile range; KPS=Karnofsky Performance Status; WHO=World Health Organization

Table 2. Operative characteristics by surgeon-volume categories.

OPERATIVE CHARACTERISTICS	Low volume	Moderate volume	High volume	p-value for difference
Skin-to-skin surgery time (min), median (IQR)	175.8 (108-246)	181.8 (132-249)	139.2 (117-165)	0.13
Extent of resection, n (%)				0.08
• Partial	2 (13)	4 (13)	0 (0)	
• Total	13 (87)	27 (87)	37 (100)	
Length of hospitalization (days), median (IQR)	7 (3-7)	6 (5-8)	7 (6-9)	0.04

IQR=interquartile range

Table 3. Postoperative outcomes by surgeon-volume categories.

POSTOPERATIVE OUTCOMES	Low volume	Moderate volume	High volume	p-value for difference
Complications (any), n (%)	8 (53)	16 (52)	23 (62)	0.66
Major complications, n (%)				
• Any	4 (27)	7 (23)	11 (30)	0.80
• Major intracranial bleeding*	2 (13)	4 (13)	2 (5)	
• New epileptic seizure†	1 (7)	3 (10)	1 (3)	
• Pneumonia	0 (0)	1 (3)	4 (11)	
• PE/DVT/sinus thrombosis	1 (7)	1 (3)	2 (5)	
• Postoperative ischemic lesion	0 (0)	1 (3)	2 (5)	
• New hemiparesis	1 (7)	0 (0)	1 (3)	
• Oculomotor paresis	0 (0)	0 (0)	2 (5)	
• Cardiac arrest	0 (0)	0 (0)	1 (3)	
• Hydrocephalus	0 (0)	0 (0)	1 (3)	
• CSF leakage requiring new craniotomy	0 (0)	0 (0)	1 (3)	
1-month mortality, n (%)	1 (7)	2 (6)	3 (8)	0.97
3-month independency, n (%)	14 (93)	21 (68)	21 (55)	0.04
1-year mortality, n (%)	1 (7)	4 (13)	10 (27)	0.15

*postoperative intracranial bleeding that caused mass effect and/or required reoperation (craniotomy or trepanation)

†epileptic seizure with convulsions and a loss of consciousness (suspected absence seizures were classified as minor complications)

CSF=cerebrospinal fluid; DVT=deep venous thrombosis; PE=pulmonary embolism

Table 4. Univariate and multivariate models about the associations between of postoperative outcomes as well as surgery volume categories and the length of surgical career (LSC) of primary surgeon.

	Univariate model, ORs (95% CIs)	Multivariate*, ORs (95% CIs)
Complications (any)		
• Per 5-year increase of LSC	1.09 (0.92-1.29)	1.07 (0.90-1.28)
• High	(Reference)	(Reference)
• Moderate	0.65 (0.25-1.71)	0.61 (0.21-1.71)
• Low	0.70 (0.21-2.34)	0.70 (0.20-2.51)
Complications (major)		
• Per 5-year increase of LSC	1.10 (0.91-1.33)	1.08 (0.88-1.32)
• High	(Reference)	(Reference)
• Moderate	0.69 (0.23-2.07)	0.65 (0.19-3.96)
• Low	0.86 (0.22-3.30)	0.97 (0.24-3.96)
1-month mortality		
• Per 5-year increase of LSC	1.19 (0.84-1.69)	1.16 (0.76-1.79)
• High	(Reference)	(Reference)
• Moderate	0.78 (0.12-5.00)	0.67 (0.06-7.98)
• Low	0.81 (0.08-8.46)	1.43 (0.10-20.02)
3-month independency		
• Per 5-year increase of LSC	0.83 (0.69-1.00)	0.85 (0.69-1.05)
• High	(Reference)	(Reference)
• Moderate	1.60 (0.59-4.33)	1.42 (0.43-4.68)
• Low	10.67 (1.27-89.80)	12.61 (1.21-131.03)
1-year mortality		
• Per 5-year increase of LSC	1.34 (1.03-1.73)	1.43 (0.99-2.07)
• High	(Reference)	(Reference)
• Moderate	0.40 (0.11-1.43)	0.25 (0.04-1.74)
• Low	0.19 (0.02-1.66)	0.15 (0.01-2.05)

*Adjusted model included IM patients' age, sex and preoperative independency.

CI=confidence interval; LSC=length of surgical career; OR=odds ratio