Predictors of Nonroutine Discharge Disposition Among Patients with Parasagittal/Parafalcine Meningioma

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OBJECTIVE: **Discharge disposition is an important outcome for neurosurgeons to consider in the context of high-quality, value-based care. There has been limited research into how the unique anatomic considerations associated with parasagittal/parafalcine meningioma resection may influence discharge disposition. We investigated the effects of various predictors on discharge disposition within a cohort of patients with parasagittal/parafalcine meningioma.**

METHODS: **A total of 154 patients treated at a single institution were analyzed (2016–2019). Bivariate analysis was conducted using the Mann-Whitney *U* and Fisher exact tests. Multivariate analysis was conducted using logistic regression. An optimism-corrected C-statistic was calculated using 2000 bootstrap samples to assess logistic regression model performance.**

RESULTS: **Our cohort was mostly female (67.5%) and white (72.7%), with a mean age of 57.29 years. Most patients had tumors associated with the middle third of the superior sagittal sinus (SSS) (60.4%) and had tumors that were not fully occluding the SSS (74.0%). In multivariate analysis, independent predictors of nonroutine discharge disposition included 5-factor Modified Frailty Index score (odds ratio [OR], 2.06; *P* = 0.0088), Simpson grade IV resection (OR, 4.22; *P* = 0.0062), and occurrence of any postoperative complication (OR, 2.89; *P* = 0.031). The optimism-corrected C-statistic of our model was 0.757.**

CONCLUSIONS: **In our single-institution experience, neither extent of SSS invasion nor location along the SSS predicted nonroutine discharge, suggesting that tumor invasion and posterior location along the SSS are not necessarily contraindications to surgery. Our results also highlight the importance of frailty and tumor size in stratifying patients at risk of nonroutine discharge disposition.**

INTRODUCTION

Discharge disposition is an important postoperative outcome for neurosurgeons to consider in the context of high-quality, value-based care.[1,2] Previous research has shown that discharge to a care facility is associated with major complications and return to the operating room within 30 days, and a 2015 study found that patients with brain tumor discharged to a care facility incurred >40% more in total hospitalization charges compared with patients who were discharged home.[3,4] Despite its proven importance, few studies have examined predictors of discharge disposition after meningioma resection and to our knowledge none have focused specifically on factors influencing discharge disposition among patients with parasagittal/parafalcine meningioma.[5-8] As described by previous investigators, the anatomy of parasagittal/parafalcine meningiomas presents a unique surgical challenge because of their proximity to the superior sagittal sinus (SSS) and to key tributary bridging veins, as well as their potential to invade into the SSS.[9,10] Although the anterior third of the SSS can generally be safely resected during surgery, there remains debate about the expendability and safety of resecting the middle and posterior thirds of the SSS.[11,12] In some patients, complete resection of meningiomas adjacent to the middle and posterior

Key words
- Meningioma
- Neuro-oncology
- Outcomes

Abbreviations and Acronyms
ASA: American Society of Anesthesiologists
mFI-5: 5-Factor Modified Frailty Index
OR: Odds ratio
SSS: Superior sagittal sinus
VIF: Variance inflation factors
WHO: World Health Organization

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thirds of the SSS may be precluded by the risk of damaging critical venous structures. However, spared morbidity may come at the cost of increased likelihood of tumor recurrence.[9,10,13-16] Anatomically complex parasagittal/parafalcine meningiomas adjacent to important midline venous structures have been shown to increase the risk of postoperative complications after surgical resection, and therefore, considerations such as anteroposterior tumor localization along the SSS and tumor invasion of the SSS are key factors to consider when studying discharge disposition in this patient population.[15]

To our knowledge, the present study is the first to examine predictors of discharge disposition among patients with parasagittal/parafalcine meningioma, specifically investigating the predictive value of tumor location, size, and extent of resection, among other key demographic and clinical variables. Our results may be useful in helping to more effectively stratify patients at risk for postoperative complications and in aiding clinicians to predict the most likely course for a patient after meningioma resection.

METHODS

Patient Selection and Recorded Variables

The present study analyzed data from 154 patients surgically treated for parasagittal/parafalcine meningiomas at a single institution between January 1, 2016 and December 31, 2019. Our institutional review board, acting as a Health Insurance Portability and Accountability Act Privacy Board, reviewed and approved the waiver of informed consent for this retrospective, Health Insurance Portability and Accountability Act—compliant study (IRB 00181593). Manual chart review of electronic medical records was used to obtain demographic, clinical, and surgical information. Tumor size was determined using postcontrast magnetic resonance images, with tumor volume measured using tumor dimensions in the axial (x), coronal (y), and sagittal (z) planes and calculated using the following formula: $\frac{x \cdot y \cdot z}{2}$. The American Society of Anesthesiologists (ASA) physical status classification system score was documented for each patient, and frailty was measured using the 5-factor Modified Frailty Index (mFI-5). ASA scores range from 1 to 6 (in increments of 1), describing patients with localized disease that does not cause systemic disturbance to patients with extreme systemic disorders and a poor physical state, respectively.[17] The mFI-5 was manually calculated by tracking the presence or absence of the following 5 medical comorbidities: functional status, history of diabetes, history of chronic obstructive pulmonary disease, congestive heart failure, and hypertension. The presence of each comorbidity corresponds to 1 point, for a minimum score of 0 and a maximum score of 5. Simpson grade was dichotomized into favorable resection (grades I—III) or unfavorable resection (grade IV). Admission type was analyzed as a dichotomized variable consisting of patients receiving emergency and nonemergency (i.e., elective) surgeries. In the present study, routine discharge disposition was defined as discharge to home (self-care) or home with health care service assistance. Nonroutine discharge disposition was defined as discharge to a rehabilitation facility, a skilled nursing facility, or a hospice facility, in line with previous research.[5]

Statistical Analysis

Data were collected using Microsoft Excel version 2016 (Microsoft Corp., Redmond, Washington, USA). Statistical analyses were conducted using R Statistical Software version 3.3.2 (r-project.org). The Mann-Whitney U test was used for bivariate analysis of continuous variables and Fisher exact test was used for bivariate analysis of categorical variables. Multivariate analysis was conducted using logistic regression, and a naive C-statistic was calculated by refitting the model to the entire data set and assessing model predictive ability. An optimism-corrected C-statistic was then calculated using 2000 bootstrap samples to account for optimism bias.[18,19] A C-statistic $\geq$0.7 was defined as constituting a clinically useful predictive model, based on criteria used in previous studies.[20-22] The Hosmer-Lemeshow test was used to assess model calibration, with a test result of $P > 0.05$ indicating adequate model fit.

Data were analyzed in 2 phases. First, bivariate analyses were performed to determine associations between patient demographic and clinical characteristics on discharge disposition. Next, a multivariate analysis was performed using the dependent variable of nonroutine discharge disposition. Covariates for this analysis included all variables that had a P value < 0.10 in bivariate analysis. Values of $P < 0.05$ were considered statistically significant and P values were reported as 2-sided.

RESULTS

Patient Demographics and Clinical/Surgical Characteristics

Our 154-patient cohort consisted of 111 patients with parasagittal meningiomas and 43 patients with parafalcine meningiomas. The cohort was mostly female (67.5%) and white (72.7%), with a mean age of 57.29 years. Most patients were not of Hispanic/Latino origin (98.1%) and were married (64.3%). Most patients in our study had private insurance (56.5%), and the remainder had Medicare, Medicaid, or where uninsured. The mean mFI-5 and ASA scores for our patient cohort were 0.58 and 2.56, respectively.

Most patients (89.0%) received scheduled surgeries through planned admissions for resection of their meningiomas; the remainder (11.0%) were admitted through the emergency department. Most patients had World Health Organization (WHO) grade I tumors (81.2%) as opposed to WHO grade II/III tumors (18.8%). The mean (standard deviation) tumor size in our cohort was 19.34 $\pm$ 21.76 cm^3. Most patients had parasagittal/parafalcine meningiomas adjacent to the middle third of the SSS (60.4%), and most patients had meningiomas that did not fully occlude the SSS (74.0%). In addition, most patients had a Simpson grade I—III resection (79.2%) versus a grade IV resection (20.8%). Mean surgical duration for our cohort was 226.85 minutes, and the mean amount of perioperative blood loss was 298.41 mL. A total of 28 patients (18.2%) had 1 postoperative complication, and 17 patients (11.0%) had >1 complication. The following postoperative complications were noted in our cohort: 16 patients (10.4%) with a new motor deficit, 12 patients (7.8%) with SSS venous thrombosis, 11 patients (7.1%) with seizures, 10 patients (6.5%) with new cognitive deficits, 6 patients (3.9%) with dysphagia, 6 (3.9%) patients with new sensory deficits, 5 patients (3.2%) with wound infection, 4 patients (2.6%) with new visual deficits, 3 patients (1.9%) with deep vein thrombosis or pulmonary embolism, 1

Table 1. Patient Demographics

Characteristic	Routine Discharge (n = 119)	Nonroutine Discharge (n = 35)	*P* Value
Mean age ± SD	56.61 ± 12.71	59.60 ± 12.42	0.21
Sex			
Male	34 (28.6)	16 (45.7)	0.066
Female	85 (71.4)	19 (54.3)	
Race			
White	89 (74.8)	23 (65.7)	Reference
African American	17 (14.3)	6 (17.1)	0.58
Asian	6 (5.0)	3 (8.6)	0.40
Other	7 (5.9)	3 (8.6)	0.44
Ethnicity			
Hispanic/Latino	1 (0.8)	2 (5.7)	0.13
Not Hispanic/Latino*	118 (99.2)	33 (94.3)	
Marital status			
Married	81 (68.1)	18 (51.4)	0.11
Not married	38 (31.9)	17 (48.6)	
Insurance			
Private	68 (57.1)	19 (54.3)	0.85
Medicare, Medicaid, or uninsured	51 (42.9)	16 (45.7)	
Frailty			
Mean 5-factor Modified Frailty Index ± SD	0.45 ± 0.66	1.03 ± 0.98	<0.001†
Mean American Society of Anesthesiologists physical status classification system ± SD	2.56 ± 0.61	2.57 ± 0.65	0.94

Values are number (%) except where indicated otherwise.
SD, standard deviation.
*Includes patients who refused to answer.
†Statistical significance ($P < 0.05$).

Table 2. Patient Clinical and Surgical Characteristics

Characteristic	Routine Discharge (n = 119)	Nonroutine Discharge (n = 35)	*P* Value
Emergency surgery			
Yes	9 (7.6)	8 (22.9)	0.026*
No	110 (92.4)	27 (77.1)	
World Health Organization grade			
I	99 (83.2)	26 (74.3)	0.32
II/III	20 (16.8)	9 (25.7)	
Mean tumor size in cm^3 ± SD	16.49 ± 18.21	31.84 ± 30.87	<0.001*
SSS localization			
Anterior third	29 (24.4)	6 (17.1)	0.57
Middle third	69 (58.0)	24 (68.6)	
Posterior third	21 (17.6)	5 (14.3)	
Tumor invasion of SSS			
Full occlusion	28 (23.5)	12 (34.3)	0.27
None/partial involvement	91 (76.5)	23 (65.7)	
Simpson grade			
I–III	103 (86.6)	19 (54.3)	<0.001*
IV	16 (13.4)	16 (45.7)	
Mean surgery duration (minutes) ± SD	213.29 ± 104.41	272.94 ± 130.41	0.0036*
Mean surgical blood loss (mL) ± SD	275.25 ± 398.37	377.14 ± 386.27	0.022*
Any postoperative complication			
Yes	26 (21.8)	19 (54.3)	<0.001*
No	93 (78.2)	16 (45.7)	

Values are number (%) except where indicated otherwise.
SD, standard deviation; SSS, superior sagittal sinus.
*Statistical significance ($P < 0.05$).

patient (0.6%) with postoperative hematoma, and 1 patient (0.6%) with a new language deficit.

Bivariate Analyses

Table 1 summarizes patient demographic characteristics for both the routine discharge cohort (n = 119) and the nonroutine discharge cohort (n = 35). Of the variables we analyzed, only a higher mFI-5 score was significantly associated with nonroutine discharge disposition ($P < 0.001$).

Table 2 summarizes patient clinical and surgical characteristics stratified by discharge disposition. Within our patient cohort, patients with a nonroutine discharge disposition were significantly more likely to have had an emergency surgery ($P = 0.026$), to have had a larger median tumor size ($P < 0.001$), to have had a Simpson grade IV resection compared with grade I–III resection ($P < 0.001$), to have had a longer surgery duration ($P = 0.0036$), to have had more perioperative blood loss ($P = 0.022$), and were significantly more likely to have had a postoperative complication ($P < 0.001$). Regarding tumor-specific factors and their association with the development of postoperative complications, neither tumor size ($P = 0.068$) nor tumor grade (WHO grade I vs. WHO grade II/III; $P = 0.22$) were significantly associated with the occurrence of postoperative complications. Although there was no significant difference between postoperative complication rates between patients with no tumor invasion of the SSS compared with patients who had partial tumor invasion of the SSS ($P = 0.12$), there was a significant difference in complication rates between patients with no tumor

invasion of the SSS compared with patients who had tumors fully occluding the SSS (P = 0.048). There was no significance difference in postoperative complication rates between patients with partial tumor invasion of the SSS compared with patients with tumors fully occluding the SSS (P = 0.67). In addition, localization along the anterior, middle, or posterior third of the SSS was not significantly associated with postoperative complications (P = 0.73). Neither localization of the meningioma alongside the anterior versus middle versus posterior third of the SSS (P = 0.57) nor extent of tumor invasion within the SSS (P = 0.27) was significantly associated with discharge disposition. Patients who had partial tumor invasion of the SSS were significantly more likely to develop SSS thromboses compared with patients who had no tumor invasion of the SSS (P = 0.019). Patients with full occlusion of the SSS were also significantly more likely to develop SSS thromboses (P = 0.036) compared with patients with no SSS tumor invasion. No significant difference in SSS thrombosis development was noted between patients with partial tumor invasion of the SSS compared with patients with tumors fully occluding the SSS (P = 1.00).

Multivariate Analysis and Model Validation

Multivariate analysis was conducted using variables that were significant in bivariate analysis. Variance inflation factors (VIFs) were calculated for each covariate, with a VIF >5 generally considered to indicate collinearity.[23] The VIFs for age (1.15), mFI-5 score (1.12), emergency surgery (1.16), tumor size (1.34), Simpson grade (1.18), surgery duration (1.39), surgical blood loss (1.27), and any postoperative complication (1.14) were all <5. The results of the multivariate analysis are summarized in Table 3. Each 1-point increase in mFI-5 score (odds ratio [OR], 2.06; P = 0.0088), unfavorable Simpson grade resection (OR, 4.22; P = 0.0062), and incidence of any postoperative complication (OR, 2.89; P = 0.031) were all independently associated with nonroutine discharge disposition. In addition, we found that a Simpson grade IV resection was significantly associated with larger tumor size (P = 0.024) and a significantly increased risk of any postoperative complication (P < 0.001). Patients who received a Simpson grade IV resection also had a greater amount of surgical blood loss relative to patients who received grade I–III resections, although this trend only approached statistical significance (P = 0.063). To validate the predictive ability of our model, we used 2000 bootstrapped samples to obtain an optimism-correct C-statistic. Our naive C-statistic was 0.802, whereas our optimism-corrected C-statistic was 0.757, suggesting that our model had a clinically useful ability to predict patients at risk of nonroutine discharge. The Hosmer-Lemeshow test showed that our model was adequately calibrated (P = 0.88).

Table 3. Multivariable Analysis of Nonroutine Discharge Disposition (n = 154)

Characteristic	Odds Ratio	95% Confidence Interval	*P* Value
Sex			
Male	1.34	0.49–3.53	0.56
Female			
5-factor Modified Frailty Index	2.06	1.20–3.59	0.0088*
Emergency surgery			
Yes	1.80	0.46–6.76	0.38
No			
Tumor size	1.02	1.00–1.04	0.10
Unfavorable Simpson grade			
IV	4.22	1.51–12.02	0.0062*
I–III			
Surgery duration	1.00	1.00–1.01	0.46
Surgical blood loss	1.00	1.00–1.00	0.28
Any postoperative complication			
Yes	2.89	1.10–7.64	0.031*
No			

*Statistical significance ($P < 0.05$).

DISCUSSION

Previous Research

Many previous studies in the neurosurgical literature have focused on determining predictors of discharge disposition. Research by Muhlestein et al.[24] found that minority race was independently associated with both extended hospital length of stay and nonhome discharge disposition among patients undergoing brain tumor resection, validating earlier work by Curry et al.[25] that reported that black patients had significantly (P < 0.001) increased odds of adverse discharge disposition after craniotomy for brain tumor. Nuño et al.,[26] examining the influence of race, gender, and tumor site in predicting various postoperative outcomes, reported that African American women had significantly more nonroutine discharges (45.1 vs. 36.8%; P < 0.0001) compared with white women and women of other races after craniotomy for brain metastases. A recent study by Harland et al.[27] reported that frailty (as measured by the Hopkins Frailty Score, ASA score, and Lee score) independently predicted discharge disposition in patients with brain tumor. Numerous studies have found that increasing surgeon and hospital volume are associated with significantly decreased rates of adverse discharge disposition.[28]

Within patients with meningioma specifically, Curry et al.[7] reported that higher-volume hospitals (P = 0.01) and increased surgeon caseload (P < 0.01) were significantly associated with decreased likelihood of adverse discharge disposition. Ambekar et al.[8] found that patient age, number of comorbidities, geographic hospital location, hospital case volume, and surgeon case volume were all significantly associated with discharge disposition. A 2018 study by Muhlestein et al.[6] used a guided machine learning ensemble model to predict discharge disposition after meningioma resection and found that the model was most strongly influenced by greater tumor size, presentation to an emergency department, greater body mass index, convexity location, and new postoperative motor deficits.

Current Study

In the present study, we sought to characterize predictors of discharge disposition specifically among patients who received craniotomies for removal of parasagittal/parafalcine meningiomas, taking into account unique surgical features of these tumor types such as extent of SSS invasion and anteroposterior location along the SSS.[9,10] Our results show that a higher mFI-5 score, unfavorable Simpson grade tumor resection, and occurrence of any postoperative complication are all independently associated with unfavorable discharge disposition. Our finding that frailty is associated with discharge disposition validates the previous results of Harland et al.[27] and Youngerman et al.,[29] while our finding that postoperative complications predict discharge disposition is in line with Muhlestein et al.'s study.[6] We did not observe a significant association between race and discharge disposition in our bivariate analysis, in contrast with previous research, although these findings may be limited by our relatively small sample size.[24-26] Although it is possible that race does not robustly predict discharge disposition among patients with parasagittal/parafalcine meningioma specifically, further research with a larger cohort is necessary to further study its relevance among this subset of patients. Our finding that tumor invasion of the SSS is significantly associated with postoperative SSS thrombosis development may be useful in guiding surgical planning as well as improving patient counseling regarding possible postoperative complications. Neither tumor anteroposterior location along the SSS nor extent of SSS invasion predicted discharge disposition. Overall, our results indicate that unfavorable anatomic localization in terms of anteroposterior location along the SSS or SSS invasion is not necessarily a contraindication to surgical resection. Preoperative planning guidelines to precisely map out the surgical approach and the extent of planned tumor removal, such as those suggested by Magill et al.,[15] are ideal for optimizing outcomes and avoiding complications in the face of complex parasagittal/parafalcine meningiomas bordering critical venous structures.

Our finding that unfavorable Simpson grade resection is significantly associated with nonroutine discharge in multivariate analysis may be because patients receiving subtotal resections have more complex and difficult tumors than do patients who are able to receive gross total resections. In addition, it is possible that such patients may have experienced intraoperative complications that prevented further tumor resection. Although the operative reports used in our study did not contain information on intraoperative complication incidence, we found that a Simpson grade IV resection was significantly associated with larger tumor size ($P = 0.024$) and with an increased risk of any postoperative complication ($P < 0.001$). Although patients who received a Simpson grade IV resection also had a greater amount of surgical blood loss relative to patients who received grade I–III resections, this trend only approached statistical significance ($P = 0.063$). Overall, these associations suggest that patients who underwent Simpson grade IV resections may have had more complex operations with a greater risk of intraoperative and postoperative complications, although further research with additional perioperative data are needed to confirm this explanation.

Our finding that occurrence of any postoperative complication is significantly and independently associated with discharge disposition is expected and serves to validate our methodology, because patients with postoperative complications are likely to require more rehabilitative services and closer monitoring compared with patients who do not experience complications after surgery. As shown by our findings that tumor occlusion of the SSS was significantly associated with the occurrence of postoperative complications ($P = 0.048$) and that the association between tumor size and the occurrence of postoperative complications approached statistical significance ($P = 0.068$), consideration of tumor-specific factors will continue to be important for ensuring optimal patient outcomes. Further investigation of these factors and their influence on postoperative complication rates specifically among patients with parasagittal/parafalcine meningioma will serve as an important avenue for future research.

Limitations

Our study has several limitations. First, our study is retrospective and would benefit from validation with a prospective study investigating the usefulness of frailty, intraoperative, and postoperative complications on predicting discharge disposition in patients with parasagittal/parafalcine meningioma. The retrospective nature of our study also prevents us from commenting on causal relationships that may exist between the variables in our statistical model and discharge disposition. Second, our data were obtained from surgeries conducted at a single institution, and it would be ideal to externally validate our results using patient data from several different hospitals.[25,28] Acknowledging these limitations, we believe that our study has yielded novel results that clarify factors influencing discharge disposition in a subset of anatomically distinct patients with meningioma.

CONCLUSIONS

Our study found that mFI-5 score, Simpson grade IV resection, and occurrence of any postoperative complication are significantly and independently associated with discharge disposition in patients with parasagittal/parafalcine meningioma, emphasizing the possible usefulness of these variables for stratifying patients at risk for nonroutine discharge. Neither extent of SSS invasion nor specific anteroposterior location along the SSS predicted nonroutine discharge, suggesting that unfavorable anatomic tumor localization is not necessarily a contraindication to surgery.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Adrian E. Jimenez: Conceptualization, Formal analysis, Investigation, Methodology, Data curation, Writing - original draft, Writing - review & editing. **Adham M. Khalafallah:** Investigation, Methodology, Data curation, Writing - review & editing. **Sakibul Huq:** Data curation, Writing - review & editing. **Melanie A. Horowitz:** Data curation, Writing - review & editing. **Omar Azmeh:** Data curation, Writing - review & editing. **Shravika Lam:** Data curation, Writing - review & editing. **Leonardo A.P. Oliveira:** Data curation. **Henry Brem:** Data curation. **Debraj Mukherjee:** Supervision, Writing - review & editing.

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