Long-Term Effectiveness of Gross-Total Resection for Symptomatic Spinal Cord Cavernous Malformations

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BACKGROUND: Intramedullary spinal cord cavernous malformations (CMs) account for 5% of all CMs in the central nervous system and 5% to 12% of all spinal cord vascular lesions, yet their optimal management is controversial.
OBJECTIVE: To identify factors associated with the clinical progression of spinal cord CMs and quantify the range of surgical outcomes.
METHODS: Retrospective observational cohort study of 32 patients who underwent open surgical resection for spinal CMs, the majority of which presented to a dorsal or lateral pial surface, from 1996 to 2017 at a single institution. We evaluated outcomes as clinically improved, worsened, or unchanged against preoperative baseline; Frankel and Aminoff–Logue disability grades were also calculated.
RESULTS: Mean age at presentation was 44.2 (range, 0.5-77 yr). Symptoms included sensory deficits (n = 26, 81%), loss of strength/coordination (n = 16, 50%), pain (n = 16, 50%), and bladder/bowel dysfunction (n = 6, 19%). Thoracic (n = 16, 50%) and cervical CMs (n = 16, 50%) were equally common, with overall mean size of 7.1 mm (range, 1-20 mm). Functional outcomes at last follow-up, compared to preoperative status for patients with >6 mo of follow-up, were improved in 6 (23%), unchanged in 19 (73%), and worsened in 1 (4%) patients. Preoperative Frankel grade and improved Frankel grade immediately following resection were strongly associated with improvement from baseline at long-term followup ($P < .01$).
CONCLUSION: Gross total resection of symptomatic spinal cord CMs can prevent further neurological decline. Our experience suggests excellent long-term outcomes and minimal surgical morbidity following resection.

KEY WORDS: Cavernous malformation, Frankel grade, Gross total resection, Spinal cord

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Cavernous malformations (CMs) are focal vascular abnormalities that arise from blood vessels supplying the brain and spinal cord. Although CMs comprise only 5% to 10% of all cerebrovascular malformations, they are recognized as an important cause of focal neurological deficits.[1,2] CMs most commonly occur in an intracranial location. Spinal cord CMs are rare and have been infrequently reported,[3-5] accounting for 5% to 12% of all spinal vascular lesions.[2,6] The natural history of spinal CMs may be characterized by repeated episodes of hemorrhage resulting in a range of neurological deficits affecting sensory, motor. and autonomic functions.[7-9] A previous report by Ogilvy et al[10] categorized 4 temporal patterns of clinical presentation and progression among 36 patients: acute episodes of neurological deficit with some recovery between episodes, an acute onset of neurological deficit followed by rapid decline, an acute onset of mild neurological deficit followed by gradual decline that lasts from weeks to months, and slow progressive neurological decline.[10]

Both spinal CMs and intracranial CMs may be associated with a family history of CMs.[11-13] Multiple brain and spinal CMs[12] have been associated with foci on chromosomes

ABBREVIATIONS: CMs, cavernous malformations; **CSF,** cerebrospinal fluid; **IONM,** intraoperative neuromonitoring; **MRI,** magnetic resonance imaging; **SEM,** standard errors of the mean.

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7q11-21, 7p13-15, and 3q25.2-27.3 using linkage analysis.[14-18] The familial form of CM demonstrates autosomal dominant inheritance with incomplete penetrance and is characterized by the development of new CMs throughout life.[19,20] Familial CM is caused by 1 of 3 gene mutations, KRIT1 (CCM1), CCM2, or PDCD10 (CCM3), although the detailed molecular mechanisms underlying formation of these inherited CMs are not yet defined.[21]

Advances in magnetic resonance imaging (MRI) have resulted in improved surveillance of spinal cord CMs over the last decade and have enabled more timely diagnosis and treatment.[22,23] One management approach is nonoperative with frequent radiological and clinical monitoring. This approach is generally recommended for CMs that remain stable on MRI and manifest with minimal symptoms in patients.[9,24] Stereotactic radiosurgery is not commonly employed as a treatment modality for either brain or spinal cord CMs because of limited evidence and suboptimal clinical outcomes.[25-28] Complete surgical resection has been proposed to treat spinal cord CMs with progressive symptoms and acute hemorrhage.[24,29-33] Analyses of surgical management have found that a shorter duration (<3 yr) of preoperative symptoms and factors regarding initial symptoms are associated with improved postoperative outcomes.[31,34,35] Another study found that a deep or ventral location of the spinal cord CM was a predictor of worse postoperative outcomes.[36]

Objective

The present study aims to provide clarity regarding the management of spinal CMs by identifying factors associated with improved long term outcomes and quantifying the range of surgical outcomes.

METHODS

Patient Population, Setting, and Study Design

The prospectively maintained vascular database of the Department of Neurosurgery at a single-institution was queried to identify all patients with spinal CMs who had been treated with surgery from 1996 to 2017. A retrospective chart review was conducted to collate clinical, lesion-specific, surgical, and outcome variables for each selected patient. This observational cohort study was completed after clearance from the Institutional Review Board and obtaining informed patient consent.

Preoperative Status Variables

Preoperative neurological and disability status were measured based on patient records. The Frankel[37] and Aminoff–Logue Disability grading[38] scales were used to evaluate baseline neurological status and disability status, respectively, prior to surgery. The following Frankel grades were used to classify neurological status: (A) complete paralysis, (B) sensory function only below the lesion level, (C) incomplete motor function below the lesion level, (D) fair to good motor function below the lesion level, and (E) normal neurological function.

The Aminoff–Logue Disability Scale is composed of 3 scores regarding the functionality of gait (0, normal; 1, leg weakness and abnormal gait without activity restriction; 2, restricted activity without requiring support; 3, 1 stick required for walking; 4, 2 sticks, crutches, or walker required for walking; 5, wheelchair confinement), urination (0, normal; 1, continent with hesitancy, urgency, or altered sensation; 2, occasional urinary incontinence; 3, total incontinence), and defecation (0, normal; 1, moderate constipation; 2, severe constipation or occasional incontinence; 3, total incontinence). The sum of gait, urination, and defecation scores yielded the following grades: (I) normal with or without minor deficits and sphincter dysfunction (total score 0-2), (II) moderate motor deficits or sphincter dysfunction with independent ambulation (total score 3-5), (III) mildly severe neurological deficits and partial sphincter dysfunction with or without independent ambulation (total score 6-8), and (IV) severe neurological deficits and total sphincter dysfunction without independent ambulation (total score 9-11).[39]

Postoperative Outcome Variables

The mean postoperative follow-up length was 40.9 mo (standard error of the mean, 8.9; range, 1-219 mo). Immediate and long-term clinical outcomes after surgical resection of spinal cord CMs were assessed from patient records. Immediate clinical outcomes were determined prior to patient discharge but after surgery. Long-term clinical outcomes were determined on the date of the last follow-up. Both immediate and long-term outcomes were evaluated as either clinically improved, worsened, or unchanged relative to preoperative baseline. Frankel grade and Aminoff–Logue Disability grade were calculated for each patient as additional measures of immediate and long-term postoperative outcomes. Long-term outcomes were only analyzed in patients with more than 6 mo of follow-up (n = 26).

Statistical Methods

Statistical calculations were conducted using the R software package (ver. 3.3.0; www.r-project.org; The R Foundation for Statistical Computing, Vienna, Austria). Summary statistics are expressed as means and standard errors of the mean (SEM). Univariate comparisons were performed with use of chi-square/Fisher's exact test (categorical variables) and the Wilcoxon rank-sum test (continuous variables). All *P* values were 2-sided, and *P* values of less than .05 were considered to indicate statistical significance.

RESULTS

Participants

We identified 32 patients with spinal CMs who were treated over the past 20 yr at our institution and suitable for inclusion in this analysis. There were 19 female patients (59%) and the mean age at presentation was 44.2 yr (SEM, 3.0). The demographic features are summarized in Table 1.

Natural History and Clinical Presentation

All patients were symptomatic. The clinical presentation of each patient was classified as previously described by Ogilvy et al[10]: an acute onset of neurological deficit followed by rapid decline (n = 6, 19%), an acute onset of mild neurological deficit followed by gradual decline that lasts from weeks to months (n = 4, 13%), discrete acute episodes of neurological deficit with some recovery between episodes (n = 9, 28%), and slow progressive neurological decline (n = 13, 41%; Table 1).

TABLE 1. Cohort Overview

Age at presentation	Sex	Ethnicity	Family history	Hx of Cranial CM	Lesion spinal level	Clinical presentation	Mean size (mm)	Duration of symptoms (mo)
49	Male	Hispanic/Latino	No	Yes	Thoracic 3-4	Slow and progressive decline	–	–
77	Female	Caucasian/White	No	No	Thoracic 10	Slow and progressive decline	–	132
20	Male	Other	No	No	Thoracic 12	Acute onset and rapid decline	7	0
64	Female	Caucasian/White	No	No	Thoracic 11	Slow and progressive decline	–	3
48	Male	Caucasian/White	No	No	Thoracic 8	Discrete and acute episodes	5	8
43	Female	Caucasian/White	No	No	Cervical 1-2	Slow and progressive decline	10	1.5
35	Male	Other	No	No	Thoracic 5	Slow and progressive decline	6	36
40	Female	Caucasian/White	No	No	Cervical 3-4	Discrete and acute episodes	5	2
44	Female	Caucasian/White	No	No	Thoracic 2-3	Discrete and acute episodes	4.8	103
56	Female	Other	No	Yes	Thoracic 8-9	Acute onset and gradual progressive decline	8	10
52	Male	–	No	No	Thoracic 7-8	Acute onset and gradual progressive decline	5	2
50	Female	Hispanic/Latino	Yes	Yes	Thoracic 12	Slow and progressive decline	12	120
51	Female	Caucasian/White	Yes	Yes	Cervical 1 and 2	Acute onset and rapid decline	7	1
70	Female	–	No	No	Thoracic 8-10	Slow and progressive decline	7	72
71	Male	–	No	No	Cervical 6-7	Acute onset and rapid decline	7	3
53	Male	–	No	No	Thoracic 11-12	Slow and progressive decline	20	24
50	Female	Caucasian/White	No	Yes	Cervical 4	Slow and progressive decline	5	12
33	Female	Caucasian/White	No	No	Thoracic 9	Slow and progressive decline	5	8
38	Female	Other	Yes	Yes	Cervical 5	Discrete and acute episodes	5	15
2	Male	Hispanic/Latino	No	No	Cervical 1-4	Acute onset and gradual progressive decline	3.5	20
61	Female	Caucasian/White	No	No	Cervical 1	Slow and progressive decline	8	24
50	Female	African American	Yes	No	Cervical 1	Acute onset and rapid decline	8	1
50	Male	–	No	Yes	Cervical 1	Acute onset and rapid decline	15	1
42	Female	–	No	No	Cervical 1	Discrete & acute episodes	15	1
63	Female	–	No	No	Cervical 3-4	Slow and progressive decline	5	36
40	Female	Hispanic/Latino	Yes	Yes	Cervical 1	Acute onset and gradual progressive decline	1	–
27	Male	Caucasian/White	No	No	Cervical 5-6	Discrete and acute episodes	5	12
31	Male	Other	No	No	Cervical 1	Discrete and acute episodes	5	36
42	Female	Caucasian/White	Yes	Yes	Thoracic 10	Acute onset and rapid decline	5	4
22	Male	Caucasian/White	No	No	Thoracic 10-11	Discrete and acute episodes	5	6
19	Male	Caucasian/White	No	No	Thoracic 5	Discrete and acute episodes	5	46
24	Female	Caucasian/White	No	No	Cervical 5	Slow and progressive decline	7	96

The overall mean duration of clinical symptoms before surgery was 27.9 mo (SEM, 6.7; Table 1). The duration of symptoms varied for each category of clinical presentation: 1.7 mo (SEM, 0.3) for patients with acute onset and rapid progression, 10.7 mo (SEM, 1.6) for patients with acute onset and gradual progressive decline, 25.4 mo (SEM, 5.8) for patients with discrete episodes, and 47.0 mo (SEM, 8.2) for patients with gradual progression. Common presenting symptoms were sensory deficits (n = 26, 81%), loss of strength or coordination (n = 16, 50%), pain (n = 16, 50%), and bladder/bowel dysfunction (n = 6, 19%). Clinical records further revealed that 9 patients (29%) presented with intracranial CMs in addition to spinal cord lesions. However, the presenting symptoms of the patients who were found to also have intracranial CMs in addition to spinal cord lesions were consistent with a spinal etiology. Six patients (19%) had a family history positive for CMs. Five of the 6 patients with family history of CMs presented with coexisting spinal and intracranial CMs ($P = .003$; Table 1).

Preoperative neurological status was assessed using Frankel grades. No patients presented with a grade A status at admission. There were 3 patients with grade B (9%), 3 patients with grade C (9%), 14 patients with grade D (44%), and 12 patients with grade E (38%) prior to CM resection. We tested associations between grade E Frankel grade and preoperative factors and found that prior history of cranial CMs was associated with some level of neurological impairment at presentation ($P = .02$; Table 2).

Preoperative disability status, measured by the Aminoff–Logue scale[38] and graded using classification from Liang et al,[39] was available for 30 patients. Twenty-one patients (70%) had grade I disability (neurologically normal or minor focal deficit,

TABLE 2. Natural History of Spinal CM and Associations With Frankel and Aminoff–Logue Grade.

	Preoperative Frankel grade grade A to D (n = 20)	Preoperative Frankel grade E (n = 12)	*P* value	Preoperative Aminoff–Logue grade I (n = 21)	Preoperative Aminoff–Logue grade II to IV (n = 9)	*P* value
Age at presentation	46.1 (3.6)	41.1 (4.9)	.31	41.8 (2.8)	49.0 (7.0)	**.03**
Female sex	13 (65.0)	6 (50.0)	.47	13 (61.9)	6 (66.7)	.47
Family history of CM	5 (25.0)	1 (8.3)	.37	4 (19.0)	2 (22.2)	1.00
Cervical spine location	9 (45.0)	7 (58.3)	.72	14 (66.7)	1 (11.1)	**.02**
Number of levels involved	1.6 (0.18)	1.4 (0.14)	.71	1.4 (0.11)	1.7 (0.32)	.83
Lesion size (mm)	8.0 (1.1)	5.8 (0.35)	.23	6.6 (0.70)	8.4 (1.7)	.15
Duration of symptoms	25.4 (8.9)	31.6 (9.7)	.23	21.7 (6.4)	40.1 (15.8)	.49
Clinical course			.93			.07
Acute, stepwise	10 (50.0)	7 (58.3)		14 (66.7)	2 (22.2)	
Progressive	10 (50.0)	5 (41.7)		7 (33.3)	7 (77.8)	
Ogilvy grade			.11			.10
Acute, rapid	4 (20.0)	2 (16.7)		4 (19.0)	2 (22.2)	
Acute, gradual	4 (20.0)	0 (0)		2 (9.5)	2 (22.2)	
Discrete, acute	3 (15.0)	6 (50.0)		9 (42.9)	0 (0)	
Slow, progressive	9 (45.0)	4 (33.3)		6 (28.6)	6 (66.7)	
History of cranial CM	9 (45.0)	0 (0)	**.02**	6 (28.6)	2 (22.2)	1.00

Statistically significant *P* values are indicated with bold font.

without or with minor sphincter dysfunction), 5 (17%) had grade II disability (mild to moderate motor deficit or sphincter dysfunction, still independently ambulating), 1 (3%) had grade III disability (less severe neurological deficiencies, handicapped, may or may not be independent, and has partial sphincter dysfunction), and 3 (10%) had grade IV disability (severe deficit, requiring wheelchair or bedridden, usually not independent, and has total sphincter dysfunction). We found that patients with a history of cranial CM were less likely to have Frankel grade E preoperatively ($P = .02$) and that patients with younger age at presentation ($P = .03$) and cervical location of the lesion ($P = .02$) were more likely to have Aminoff–Logue grade I preoperatively. Acute-stepwise clinical course demonstrated a trend toward significance ($P = .07$) for Aminoff–Logue grade I prior to resection (Table 2).

Lesion Location and Surgical Procedures

In this patient series, most spinal cord CMs resected were superficially located and presented to a dorsal or lateral pial surface, but some extended deeper to involve the central or ventral cord. Surgical resection was complete for all cases. The OmniGuide CO_2 laser (OmniGuide, Lexington, Massachusetts) with 0.55 mm fiber was used to resect the CM in the last 15 cases, and considered the safest technique for resection. Intraoperative neuromonitoring (IONM) of arm, leg, and anal function was utilized in all patients (n = 30) for whom these data were recorded. Persistent, significant IONM changes were observed in 13 patients. Most patients underwent a total laminectomy/laminoplasty with hemilaminectomy performed for 1 patient. Clinical data about CM size were available in 29 patients; the mean size of the CM was 7.1 mm (SEM, 0.7; Table 1). The locations of the lesions were cervical (n = 16, 50%) and thoracic (n = 16, 50%).

We assessed for complications of pneumonia, deep vein thrombosis, cerebrospinal fluid (CSF) leak, wound infection, serous fluid collection, delayed kyphosis, tethered cord, and stenosis. Only 2 patients (6%) presented with an operative or immediate complication of CSF leak and 1 patient (3%) with both a CSF leak and serous fluid collection. Thirty-day complications were seen in only 1 patient, the same patient, for serous fluid collection, though the CSF leak had resolved. No patients had any post 30-d complications in the above categories. No patients required corrective surgery after CM resection.

Immediate Postoperative Outcomes

Early postsurgical outcomes were available for 31 patients and were as follows: Frankel grade C – 5 (16%), grade D – 14 (45%), and grade E – 12 (39%). At initial discharge, 4 patients had worsened by 1 Frankel grade (13%), 2 patients remained unchanged (68%), and 6 patients (19%) had improved by at least 1 Frankel grade. Disability status immediately after surgery was available for 30 patients, with the following Aminoff–Logue grades: grade I in 12 patients (40%), grade II in 9 patients (30%), grade III in 7 patients (23%), and grade IV in 2 patients (7%). We found that IONM changes were associated with worsened Frankel grade ($P = .03$) but not with worsened Aminoff–Logue grade ($P = .18$), while use of the CO_2 laser was associated with improved Frankel grade ($P = .02$), but not with improved Aminoff–Logue grade ($P = .48$) immediately following resection.

Long-Term Follow-up Outcomes

We limited our assessment of long-term outcomes (n = 26) to patients with follow-up >6 mo. Mean follow-up in these patients was 49.7 mo (SEM, 10.2). Neurological status was either Frankel grade D (n = 14, 54%) or grade E (n = 12, 46%). One patient (4%) had worsened by 1 Frankel grade, 19 patients (73%) remained unchanged, and 6 patients (23%) had improved by 1 grade at last follow-up. Aminoff–Logue Disability status at the last follow-up, as measured in 24 patients, was grade I in 16 patients (67%), grade II in 6 patients (25%), and grade III in 2 patients (8%). There were no patients with the most severe grade IV disability. At last follow-up, 4 patients (18%, of 22 patients with both baseline and last follow-up Aminoff–Logue grade) had improved Aminoff–Logue grade, 16 patients (73%) were unchanged, and 2 patients (9%) had worsened Aminoff–Logue grade. Figure depicts patient-level trajectories over time, with regard to neurological (Figures A-C, Frankel) and disability (Figures D-F, Aminoff–Logue) grades.

We investigated factors associated with improved long-term outcomes by defining "improved long-term" as improvement from preoperative status in *either* Frankel grade of Aminoff–Logue grade (n = 6). Univariate analysis revealed that preoperative Frankel grade ($P = .004$) and improvement of Frankel grade immediately following resection ($P = .001$) were strongly associated with improved long-term outcomes. While sensory presenting symptoms ($P = .06$) and preoperative Aminoff grade ($P = .06$) differered between patients who had long-term improvement compared to those with long-term stable or worsened, these variables did not reach statistical significance (Table 3).

DISCUSSION

Key Results

The findings from this study suggest that surgical resection of spinal cord CMs can be performed effectively in the appropriate patient population. Complete resection of the CM could be achieved in all patients, and only 2 patients in our series (6%) had immediate postsurgical complications in the form of a CSF leak and/or serous fluid collection, both of which resolved within 30 d. Overall, surgical management of the patients was associated with improved clinical, neurological, and disability outcomes. These results are consistent with results from Zhang et al,[40] comparing surgical and conservative management of spinal CMs, and long-term results reported by Mitha et al.[7]

In this study, the average age at presentation was 44.2 yr, which is consistent with previously published reports on the epidemiological features of spinal cord CMs that tend to present around the third to fourth decades of life.[8,39] A recent meta-analysis found that 11.9% of patients demonstrated a positive family history of CMs[8] However, there does not appear to be a statistical difference in the age at presentation between patients with and without a family history of CMs.[7] A family history of CMs was found to be associated with a higher risk of having both spinal and intracranial CMs; the rate of multiple CMs in patients with a positive family history of CMs was significantly higher than those without a family history.[13,20,41] Six patients (19%) in this study had a family history of CMs. We also observed that a number of patients without a family history also harbored intracranial CMs. The prevalence of concurrent spinal and intracranial CMs has been found to be as high as 40% of patients in some series.[8] In this study, 9 patients (29%) were found to have concomitant cranial and spinal CMs. Of these 9 patients, 5 had a documented family history of CMs It is thus necessary to screen the entire brain and spinal cord in any patient who presents with a CM—be it cranial or spinal.

The clinical presentation involving a slow progressive neurological decline was the most frequent in our patient series. A meta-analysis of individual patient data by Badhiwala et al[8] found that spinal cord CMs are often clinically slowly progressive, though neurological recovery was found to be better at follow-up for patients with an acute onset and stepwise decline rather than a slow progressive decline.[8] However, we found no difference in final outcomes between patients with acute or more chronic clinical presentations in our cohort of patients. At our institution, all symptomatic spinal CM patients were offered surgical resection as the optimal treatment. Thus, patients in this series underwent a complete surgical resection of their spinal lesions, thereby disallowing a comparison between the merits of surgical versus conservative treatment. Generally, conservative treatment (with close clinical and radiological follow-up) is recommended for radiographically stable CMs with minimal symptoms, as well as in those cases where surgery is too high-risk—such as spinal CMs that are located ventrally.[9,24,42] In one study by Labauge et al,[36] postoperative clinical improvements were seen more often in patients whose spinal cord CMs were found in a posterior rather than anterior location. While the meta-analysis by Badhiwala et al[8] did not find a significant association between cavernoma location and improved outcomes, the study did demonstrate that patients who were treated surgically rather than conservatively often had better neurological outcomes. The findings from this study further emphasize the favorable postoperative outcomes associated with surgical management in addition to the feasibility of performing complete surgical resections on spinal cord CMs.

Limitations

A limitation of our study is the retrospective design and relatively small number of patients with spinal CM. In addition, we calculated disability and neurological status scores based on retrospective review of detailed clinical notes, which are subject to potential errors in the charting or individual physician representation of the patient. However, the rare nature of this lesion necessitates continued reporting of outcomes by institutions with extensive experience managing these patients.

Interpretation

In this series, 96% of our total patients (n = 26) with available follow-up after 6 mo were either neurologically stable or improved

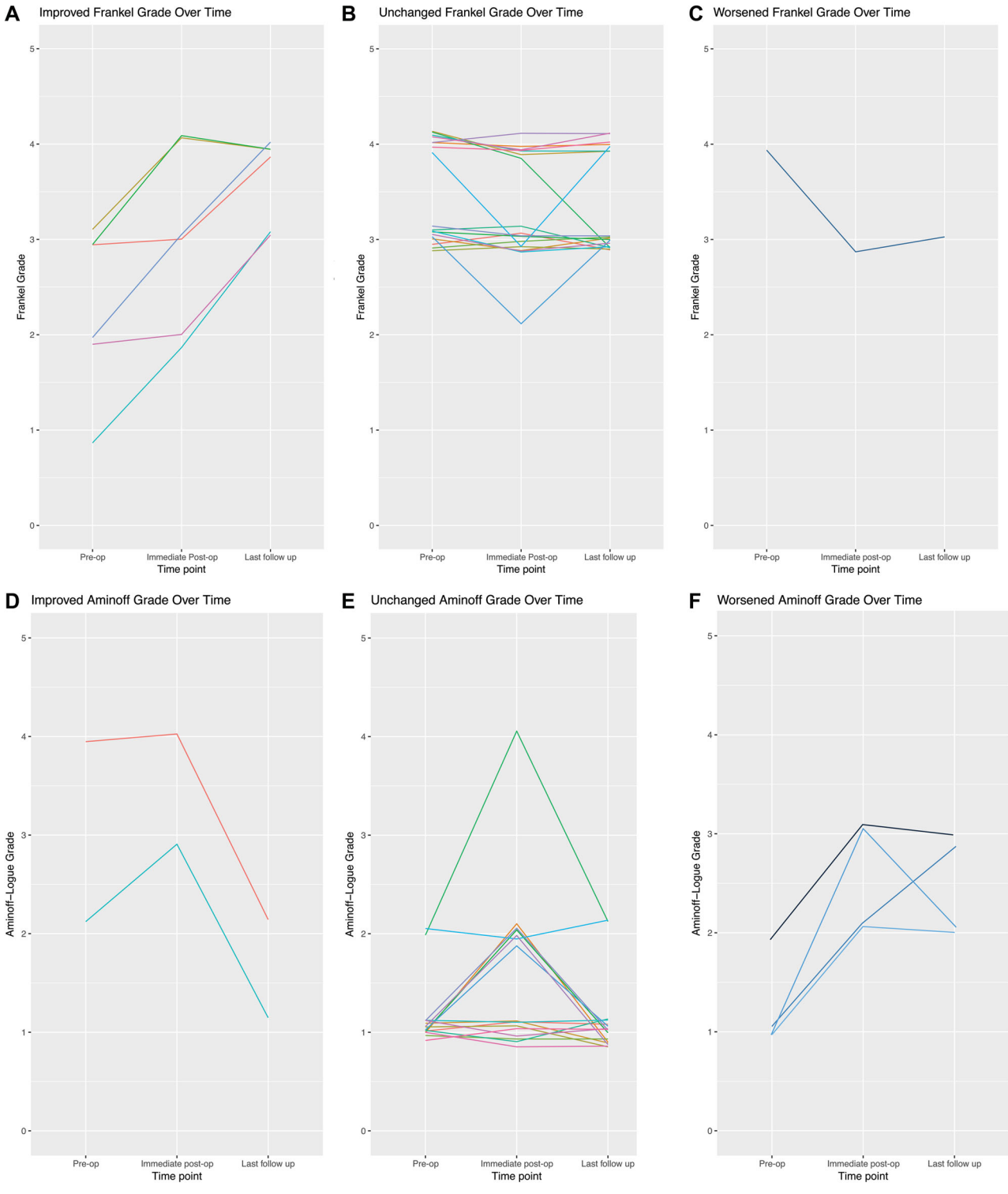

FIGURE. *Patient-level trajectories over time:* **A-C**, *neurological (Frankel) and* **D-F**, *disability (Aminoff–Logue) grades.*

TABLE 3. Predictors of Long-Term Improvement in Patients With ≥6 mo of Follow-up.

Variable	Long-term improvement (n = 6)	Long-term stable or worsened (n = 20)	*P* value
Mean age at presentation	37.8 (7.2)	48.4 (3.2)	.38
Female sex	2 (33.3)	14 (70.0)	.25
Spinal level	2 (0.41)	1.5 (0.13)	.29
Mean lesion size (mm)	6.3 (1.2)	6.9 (0.75)	.60
Cerebral cavernous malformation	2 (33.3)	6 (30.0)	
Family history	1 (16.7)	4 (20.0)	1.00
Clinical course			.64
Acute, stepwise	3 (50.0)	13 (65.0)	
Progressive	3 (50.0)	7 (35.0)	
Presenting symptoms			
Motor	4 (66.7)	9 (45.0)	.64
Sensory	3 (50.0)	18 (90.0)	.06
Pain	3 (50.0)	9 (45.0)	1.00
Bladder/bowel	1 (16.7)	3 (15.0)	1.00
Duration of symptoms (days)	36 (6.1)	25.4 (9.4)	.57
Preoperative Frankel grade			**.004**
A	0 (0)	0 (0)	
B	1 (16.7)	0 (0)	
C	2 (33.3)	0 (0)	
D	3 (50.0)	10 (50.0)	
E	0 (0)	10 (50.0)	
Preoperative Aminoff grade			.06
I	2 (33.3)	17 (85.0)	
II	1 (16.7)	3 (15.0)	
III	0 (0)	0 (0)	
IV	1 (16.7)	0 (0)	
Use of CO_2 laser	1 (16.7)	11 (55.0)	.17
IONM change	1 (16.7)	10 (50.0)	.33
Improved Frankel grade immediate postoperative	4 (66.7)	0 (0)	**.001**

Statistically significant *P* values are indicated with bold font.

at last follow-up. Interestingly, patients who had neurological improvement at long-term follow-up often had worse preoperative Frankel grades; this may be due to their lower neurological status at baseline, which would therefore provide a greater opportunity for noticeable improvement. Furthermore, improvement immediately following resection was also predictive of long-term improvement. Thus, patients with poor Frankel grade at presentation should not be selected against for surgical management—our results suggest that these patients may benefit significantly from complete resection and can achieve excellent long term outcomes.

CONCLUSION

Gross-total resection of symptomatic spinal cord CM can prevent further neurological decline in the majority of patients. Our experience suggests that resection of spinal cord CM can be achieved with excellent long-term outcomes and minimal surgical morbidity.

Disclosures

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COMMENT

The authors provide a comprehensive retrospective review of their experience in resecting accessible, symptomatic spinal cord cavernous malformations. Most reached a dorsal or lateral pial surface and were superficially located in the cervical or thoracic spinal cord. In the subset of patients for which follow-up is available, most remained neurologically unchanged or improved, irrespective of the acuity of presentation. The authors are commended for their excellent results.

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