

# Surgical Management of Pontine Brainstem Cavernous Malformations: A Systematic Review Emphasizing Safe Entry Zones and Clinical Outcomes



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### Introduction

The eloquence of the brainstem parenchyma and the presence of critical neurovascular structures make surgical resection of brainstem cavernous malformations (CM) a formidable task (1). Despite advancements in microsurgical techniques, morbidity associated with surgical resection of BSCM remains high, with rates reported up to 35% (1). The use of safe entry zones (SEZs) has emerged as a key strategy to minimize surgical morbidity and improve patient outcomes in the treatment of brainstem CM.

SEZs are specific anatomic corridors that allow for safe surgical access to the brainstem while minimizing the risk of injury to critical neural and vascular structures (2). These zones are defined by the surface anatomy of the brainstem and the location of the underlying nuclei and fiber tracts (2). The use of SEZs in brainstem CM surgery was first described by Kyoshima et al. in 1993 and has since been refined and expanded by several authors (3-5).

Table 1. Pontine CM characteristics		Table 2. Follow-up outcome for pontine CM		
<b>BSCM Characteristic</b>	Outcome	Surgical Outcome Descriptor	Outcome	
		Gross total resection	54 (69.2%)	
DVA	6 (7.69%)			
Size(mm)	14.36±8.17	Follow-up time (years)	4.84±4.27	
Location		Pre-operative mRS	$1.95 \pm 1.42$	
		Post-operative mRS	$2.09 \pm 1.42$	
Basilar	2 (3.13%)	Last Follow-up mRS	$1.07 \pm 1.30$	
Peritrigeminal	38 (59.4%)	Good clinical outcome (mRS<2)	50 (64.1%)	
Middle Peduncular	16 (25.0%)	Stable clinical outcome (no change in	21 (26.9%)	
Inferior peduncular	2 (3.13%)	mRS)		
Rhomboid	6 (9.4%)	Worse clinical outcome (mRS>2)	6 (7.7%)	
Cross-Midline	2 (2.56%)	Complication	11 (14.1%)	



### Objective

This systematic review and meta-analysis aims to provide a comprehensive analysis of the surgical management of pontine CM with a focus on the use of SEZs.

## Methods

Literature review of PubMed utilizing the search terms: "pons" and "cavernoma" or "cavernous hemangioma" or "cavernous angioma" or "cavernous malformation".

Inclusion criteria were:

- (1)case series, prospective or retrospective cohort studies, or clinical trials reporting surgical management of pontine CM
- (2)Studies reporting data on post-operative outcomes, including number of pre-operative hemorrhages, annual hemorrhage

**Pre-Operative mRS** 

**Post-Operative mRS** 

#### **Table 3.** Safe entry ones for resection of pontine CM

Safe Entry Zone	Frequency	Location of	GTR	Change in
	N(%)	BSCM	N(%)	mRS
Lateral Pontine Zone (A)		Peritrigeminal		
	35 (52.2)	Middle	85.7	-0.657±1.4
		Peduncle		
Peritrigeminal Zone (B)	12 (17.9%)	Middle	50.0	-0.182±0.8
		Peduncle		
Supratrigeminal Zone (C)	8 (11.9%)	Middle	62.5	-1.29±1.7
		Peduncle		
Infracollicular Zone ( <b>D</b> )	8 (11.9%)	Inferior	75.0	-0.875±0.8
		peduncle		

rate, re-hemorrhage rate, and time from hemorrhage to surgery. Distribution within pons categorized according to location as defined by taxonomy proposed by Catapano et al. (6).

# Results

A total of 78 patients with an average age of  $37.62\pm14.7$  years were described in the included reports. The average duration of preoperative symptoms was  $129.9\pm233$  weeks and 35 (44.9%) cases had a hemorrhagic presentation with an average of  $1.84\pm1.0$  preoperative hemorrhagic events (**Table 1**). The average pre-operative modified Rankin scale (mRS) was  $1.95 \pm 1.42$ . The most common presenting symptoms were hemiparesis (56.4%), ataxia (48.7%) and headache (42.6%).

Gross total resection was achieved in 69.2% of cases and 64.1% of patients had good clinical outcomes (follow-up mRS score of less than 2) (**Figure 1**) (**Table 2**).

The LPZ had the greatest rate of gross total resection (85.7%) and the PTZ had the lowest rate of gross total resection (50.0%) (**Table 3**). Chi-square analysis revealed differences in gross total resection between SEZ were significant (p=.042).

The rate of post-operative re-hemorrhage was 8.97% and there was no difference between rates of re-hemorrhage between SEZ (p=.414).

# Discussion

The overall morbidity and mortality rates associated with surgical resection of pontine BSCM in this meta-analysis were lower than previously reported rates in meta-analysis of resection of pontine BSCM without controlling for use of SEZ. New or worsened neurological deficits occurred in 7.7% in our cohort, while in comparison, previous studies have reported neurological morbidity rates up to 35% and mortality rates up to 6.3%. (7). Aside from use of SEZ, the lower rates observed in this study may be attributed to advancements in surgical techniques, intraoperative neuromonitoring, and image guidance.

### Conclusions

The surgical resection of pontine CMs can be achieved with acceptable morbidity and mortality rates with SEZ utilization. The most common SEZ utilized in the pons is the LPZ which was associated with the highest rate of gross resection. The choice of SEZ and approach depends on the CM's location, emphasizing the importance of surgical anatomy knowledge.

Complications occurred in 14.1% and Complication rates were found to be statistically significant between SEZ groups (p=.026).

# Contact

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