Clinical and Surgical Management of Cavernous Sinus Meningiomas: Guidelines and Surgical Perspectives

Paolo Alimonti, MD[1] and Lucia Zamorano, MD,FAANOS,FICS[2]

1. Postdoctoral Research Fellow, Department of Neurosurgery, Brigham and Women's Hospital, Harvard Medical School, Boston, MA
2. Professor of Neurosurgery William Beaumont Oakland University School of Medicine

MICHIGAN BRAIN & SPINE SURGERY CENTER

Epidemiology

- Cavernous Sinus Meningioma (CSM) represents 1% of all intracranial meningeal tumors (0.5 per 100,000 incidence)
- Mostly benign (WHO grade I)
- Plethora of alternative etiologies in DDx:

  - Meckel cave/petroclival meningiomas
  - CS hemangioma
  - trigeminal schwannoma
  - metastases
  - chordoma/chondrosarcoma
  - nasopharyngeal carcinoma
  - pituitary adenoma

Chotai et al., *Asian J Neurosurg,* 2018
Corniola et al., *Brain and Spine*, 2022

Clinical Presentation

- Multiple cranial nerve deficits (III-VI)
- Cavernous sinus syndrome
- Tolosa-Hunt Syndrome
- Endocrine disturbances
  - hyperprolactinemia
  - hypopituitarism (rare)

Corniola et al., *Brain and Spine*, 2022

Pathology: Topographic Classification

Normal CSM Type I CSM Type II CSM Type III

Type I: inward growth	Type II: outward growth from lateral CS wall	Type III: outward growth from medial wall
- from arachnoid granulations of CS itself; - encases neurovascular structures of the CS;	- exophytic growth towards the temporal lobe; - medial displacement of CS neurovascular structures;	- growth towards the CS; - outward displacement and spreading of CNs;
unfit for surgery, radiation advised	**suitable for craniotomy**	**suitable for EEA**

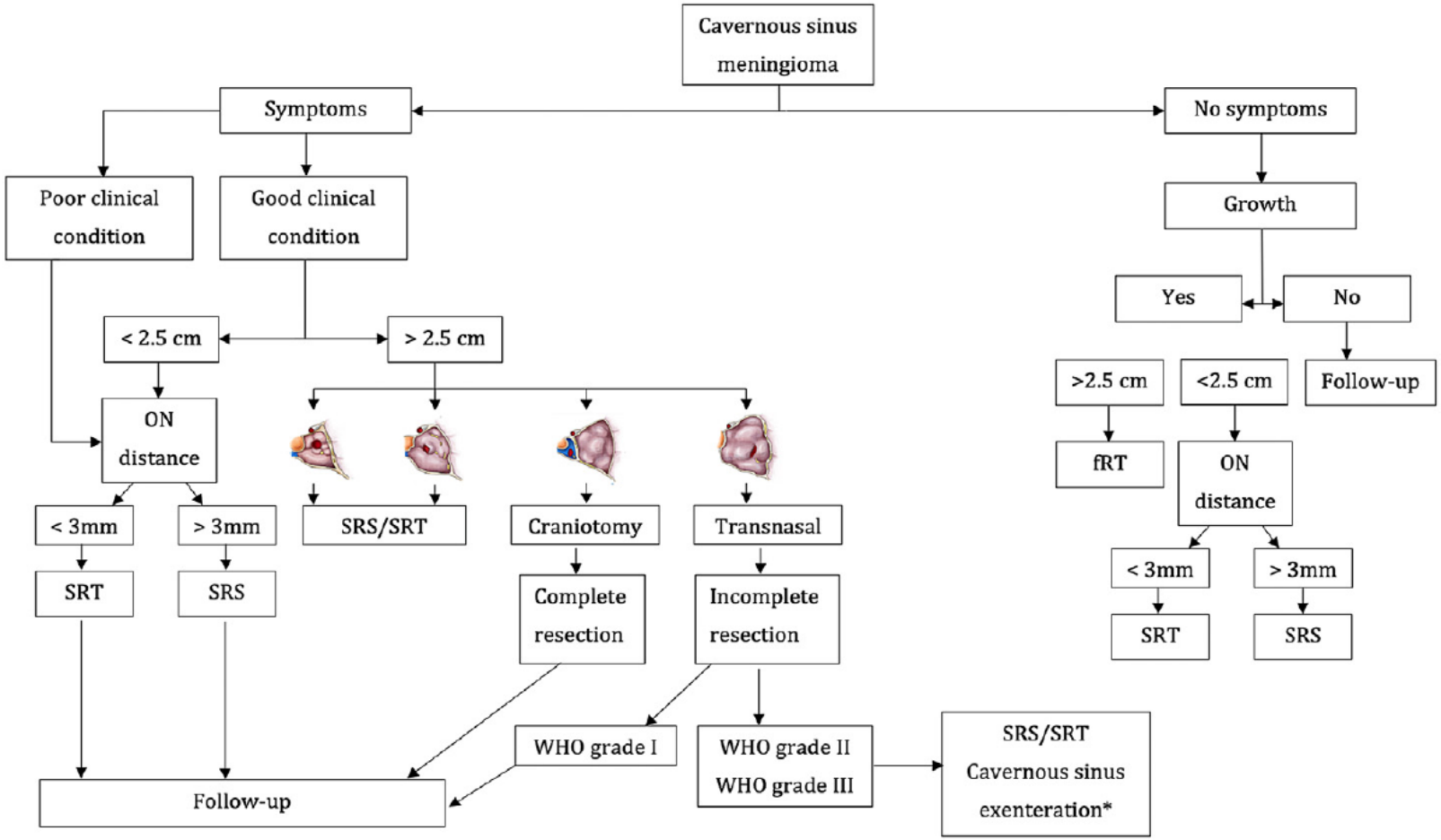
Corniola et al., *Brain and Spine*, 2022

Imaging and Evolution

- Standard CT→ calcifications, hyperostosis and bone erosion
- Perfusion CT→ functional reserve and patency of intracavernous ICA
- MRI sequences:
  - contrast T1,T2, TOF→ dural attachment and relationship with neurovascular structures
  - T2 CISS→ course of CNs in lateral CS wall
- Imaging for annual growth monitoring and patient stratification:
  - **< 5%** → no growth;
  - **5-20%** → slow growth;
  - **> 20%** → increased growth (20-100% medium, >100% fast);
- Average tumor growth rate: 1.34 cm^3/yr; Mean doubling time: 13.6 yrs

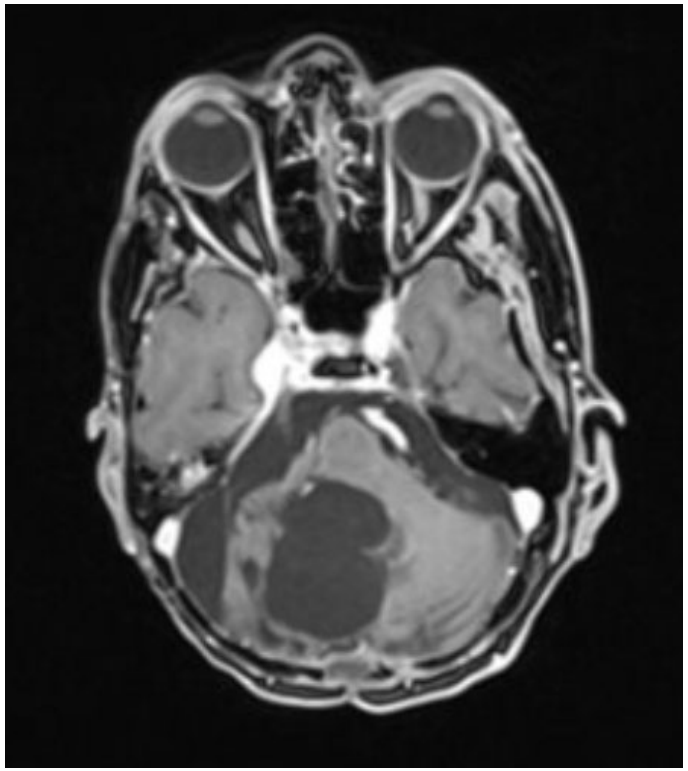
Corniola et al., *Brain and Spine*, 2022
Benjamin et al., *J Neurosurgery*, 2021

Management: the EANS Guidelines



Corniola et al., *Brain and Spine*, 2022

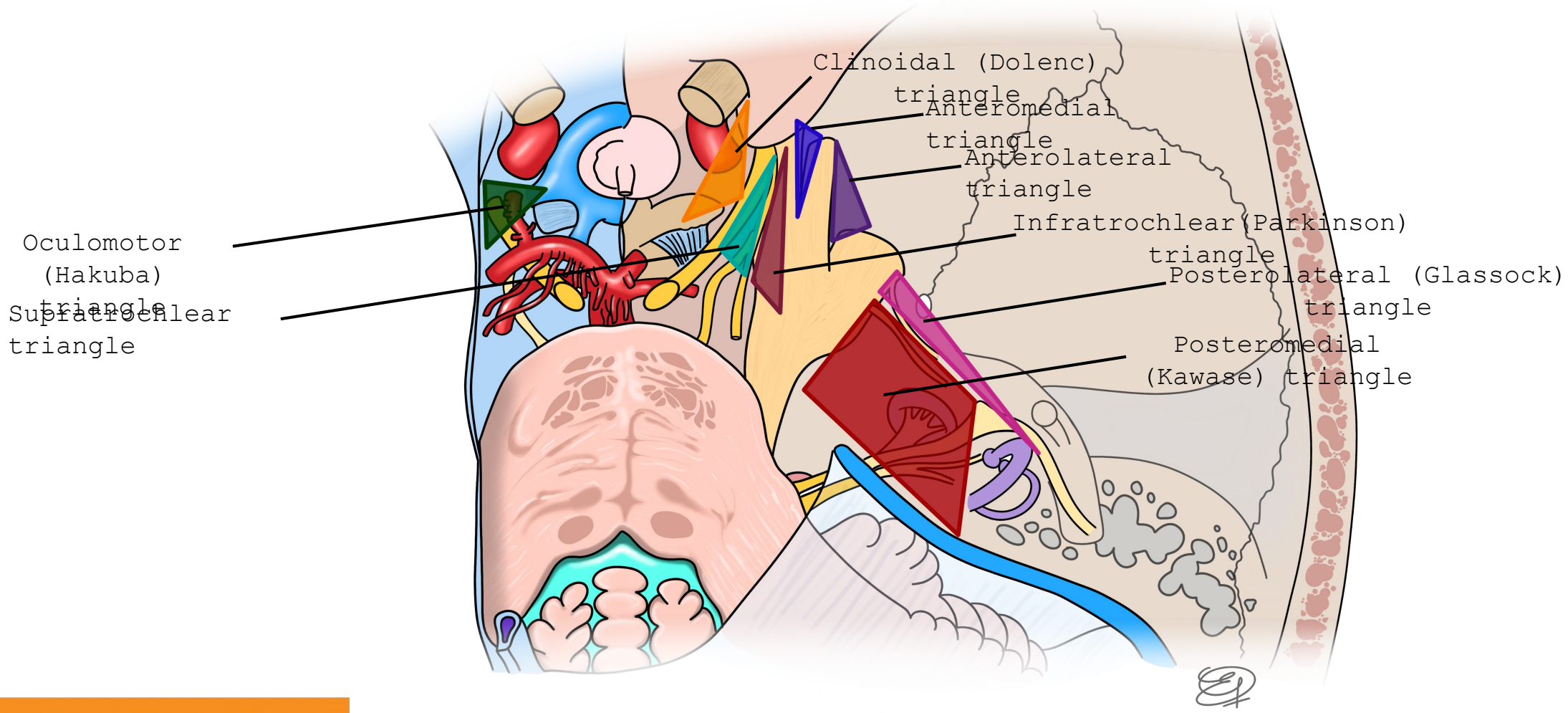
Case Presentation



72 yo male, resection of posterior fossa lesion in pediatric age; image shows R CSM; recommended for GK RT

MICHIGAN BRAIN & SPINE SURGERY CENTER

CS Anatomy: the «Jewel Box»



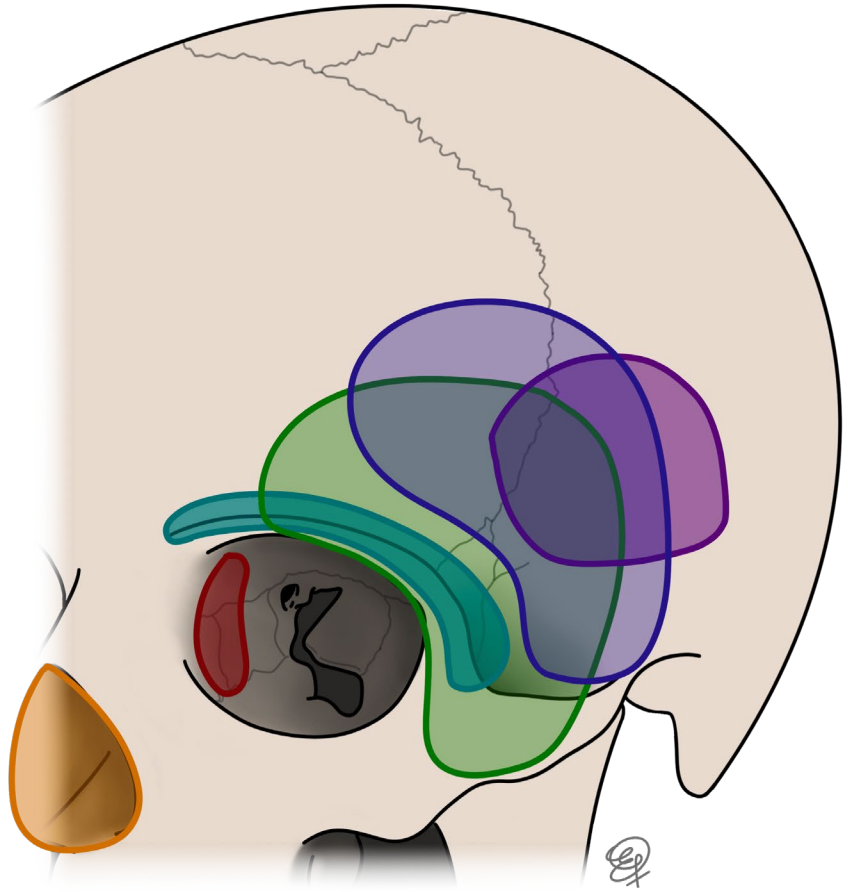
Surgical Anatomy

Triangles	Clinoidal (*Dolenc*)			Supratrochlear			Infratrochlear (*Parkinson*)			Anteromedial (*Mullan*)			Anterolateral		
Boundaries	- Lower border of II c.n. superiorly; - Upper border of III c.n. inferiorly			- Lower border of III c.n. superiorly; - Upper border of IV c.n. inferiorly			- Lower border of IV c.n. superiorly; - Upper border of V1 inferiorly			- Lower border of V1 superiorly; - Upper border of V2 inferiorly			- Lower border of V2 superiorly; - Upper border of V3 inferiorly		
Approach	FTOZ	SETOA	EEEA	FTOZ	SETOA	EEEA	FTOZ	SETOA	EEEA	FTOZ	SETOA	EEEA	FTOZ	SETOA	EEEA
Surgical maneuvers for the exposition	Anterior clinoidectomy (augmented by pericavernous maneuvers)	Anterior clinoidectomy	---	Peeling of the LWCS and middle fossa	Peeling of the LWCS and middle fossa	---	Peeling of the LWCS and middle fossa	Peeling of the LWCS and middle fossa	---	Peeling of the LWCS and middle fossa	Peeling of the LWCS and middle fossa	Removal of lateral wall of the sphenoid sinus	Peeling of the LWCS and middle fossa	Peeling of the LWCS and middle fossa	Removal of lateral wall of the sphenoid sinus
Content	cl-ICA, between upper and lower dural rings	cl-ICA, between upper and lower dural rings	Optic strut or optic-carotid recess	hc-ICA and MHT, ILT	hc-ICA	---	Posterior bend of the c-ICA with MHT, VI c.n.	Superior half and posterior bend of posterior c-ICA with MHT	ILT; VI c.n.	Sphenoid sinus	Inferior half of the posterior segment of c-ICA; VI c.n.	Venous structures	Sphenoid sinus	Lacerum ICA; Sympathetic carotid plexus; FL; PLL; Vidian nerve and artery;	---
Indications	Meningioma ACP, carotid-ophthalmic aneurysm	Meningioma ACP	---	Schwannomas, CS tumors	Schwannomas, CS tumors	Pit-adenoma, chondrosarcomas with lateral extension up to the CS lateral wall	Aneurysm or fistula of proximal c-ICA, CS tumors	Schwannom CS tumors	Pit-adenoma, chondrosarcomas with lateral extension up to the CS lateral wall	Middle fossa tumors with CS invasion	Small lesion involving the anteroinferior compartment of CS	Pit-adenoma, chondrosarcomas with lateral extension up to the CS lateral wall	---	Small lesion involving the anteroinferior compartment of CS	Pit-adenoma, chondrosarcomas with lateral extension up to the CS lateral wall
Safety of surgical access	Low risk	Low risk	Low risk	Mid risk	Mid risk	Mid risk	Mid risk	Mid risk	Mid risk	Low risk	Mid risk	Low risk	Low risk	Low risk	Low risk

c.n.: cranial nerve; FTOZ: fronto-temporal-orbito-zygomatyc; SETOA: superior eyelid transorbital endoscopic approach; EEEA: extended endoscopic endonasal approach; cl: clinoid; hc: horizontal cavernous; CS: cavernous sinus; c-ICA: cavernous internal carotid artery; Pit: pituitary; LWCS: lateral wall cavernous sinus; ICA: internal carotid artery; PLL: petro-lingual ligament, MHT: meningo-hypophyseal trunk; ILT: inferolateral trunk, FL: foramen lacerum.

Corvino et al., *Brain Sciences, MDPI*, 2023

Surgical Approaches



- Pterional/Dolenc
- Kawase
- Orbitozygomatic/Hakuba
- Supraorbital
- Endoscopic Transnasal/Trans-sphenoidal
- Transorbital Precaruncular

MICHIGAN BRAIN & SPINE SURGERY CENTER

Surgical Approaches

APPROACH	ADVANTAGES	DISADVANTAGES
Orbitozygomatic (OZ or Hakuba)	- wide access to SOF, CS, orbit, anterior and middle fossa; - greater angle of view and instrument manipulation;	- wide skin incision and consistent bone removal; - reconstruction required for optimal cosmetic outcomes;
Anterior Clinoidectomy with Extradural Peeling (Dolenc)	- early identification and protection of optic apparatus; - access to both anterior and posterior CS; - identification of CN III, IV, V1 and V2 at SOF convergence;	- Higher risk of postoperative ocular complications compared to standard pterional approach;
Anterior Transpetrosal Transtentorial (Kawase) Approach	- useful for medially-extending meningiomas; - can be combined with other cranial base approaches for extensive lesions;	Drilling of the petrous part of the temporal bone may pose risk of: - carotid injury; - hearing loss; - nasal liquorrhea;
Translateral Orbital Wall Approach	Faster and less invasive than OZ; can be endoscope-assisted to reach posterior CS	Indicated only for small tumors located in lateral or superolateral orbit and extending in lateral CS wall;

Hakuba et al., *Neurol Med Chir,* 1982; Dolenc, *J Neurosurg.,* 1983;
Kawase et al., *Neurosurgery*, 1991; Matsuo et al., *Oper Neurosurg*, 2016

Other Surgical Approaches

APPROACH	ADVANTAGES	DISADVANTAGES
Supraorbital keyhole	Fully exposes the anterior fossa up to the prepontine cisterns	No access to the anterior portion of the middle fossa and the CS
Retrosigmoid	Access to the posterior portion of middle fossa and the Meckel's cave	Cannot reach the juxta-cavernous region
Posterior petrosectomy	Wide exposure to both the posterior fossa and the petroclival region	Trajectory in conflict with frontalis branch of facial nerve
Minipterional	Access to the anterior part of middle cranial fossa	- Poor cosmetic outcomes; - Significant soft tissue trauma;

Jean et al. *Oper Neurosurg*, 2020

Transorbital Approaches

- Precaruncular (medial canthal) approach

ADVANTAGES
- direct and avascular approach to CS; - rapid healing without scarring;

- incision at conjunction of skin and conjunctiva
- periorbita elevation along medial orbital wall (lamina papyracea)
- subperiosteal, floor-to-roof dissection
- craniotomy through medial orbital wall, at the junction between orbital roof and fovea ethmoidalis

Jean et al. *Oper Neurosurg*, 2020
Vural et al., *Neurosurg Review*, 2018

Endoscopic Approaches

- Transnasal Transphenoidal approach

ADVANTAGES
- exposes CS and inferomedial 1/3 of SOF; - decompresses bony walls of CS and bears good CN function recovery; - best suited for small-to-medium, soft tumors with minimal risk of ICA infiltration; - increased visualization, less morbidity compared to microscopic transsphenoidal technique;
DISADVANTAGES
- inadequate exposure the lateral CS wall; - not useful for lesions extending beyond the Meckel's cave;

Chotai et al., *Asian J Neurosurg.,* 208
Corniola et al., *Brain and Spine*, 2022
Li et al., *Head and Neck*, 2020
Taussky et al., *J Neurosurg*, 2011

Combined Open Approaches-I

AUTHORS	APPROACH	OUTCOME	CLINICAL DETAILS
Elshamy et al.	Transcavernous + Kawase	GTR	adjuvant RT
Nonaka et al.	Transzygomatic transcavernous + extended middle fossa	GTR	- CN3 palsy and facial anesthesia; - rhinorrhea requiring skull base endoscopic reconstruction;
Nonaka et al.	Transcavernous anterior and middle infratemporal fossa with ICA-ECA saphenous vein bypass	GTR	Recurrent in and around CSM; - transient motor aphasia and hemiparesis; - postoperative CN3 palsy and facial anesthesia
Sabit et al.	Extranasal Transmaxillary Transphenoidal	N/A	anatomic study on 12 cadavers and 2 head specimen
Morisako et al.	Combined anterior-posterior transpetrosal	59-95% EOR	series of 9 cases; - 5/9 (56%) without new-onset deficits; - 1/9 (11%) with complete deficit recovery; - 2/9 (22%) with partial deficit recovery; - 1/9 (11%) with new-onset postoperative deficit;
Fong et al.	Anterior and posterior petrosectomy	Improvement in trigeminal pain	Single case of recurrent, post-RT meningioma of CS, Meckel's cave and petroclival region with superior cerebellar artery neurovascular conflict; MVD was performed during surgery;

Combined Open Approaches-II

AUTHORS	APPROACH	OUTCOME	CLINICAL DETAILS
Sun et al.	Extended middle fossa and lateral sphenoidectomy	GTR	Series of 22 cases of meningiomas and other pathologies all involving CS, along with several skull base structures; - GTR: 5/22 (23%); - NTR: 11/23 (50%) - STR: 6/23 (27%) - New-onset postoperative CN deficits in 55% (CN5 most common, followed by CN3,4,6), CSF leak 9%, hydrocephalus 18%, seizures 9%
Aboud et al.	Two-stage, double Anterior and posterior petrosectomy	GTR	Extended petroclival-cavernous meningioma
Fukushima et al.	Extradural total petrous apex resection with Trigeminal Translocation	N/A	Anatomic study on 20 cadavers; improved visualization of the posterior CS and petroclival region
Chen et al.	Pretemporal transcavernous trans-Meckel's transtentorial transpetrosal		109 meningioma patients in fours defined zones: 42 (38.5%) in zone I (sphenoid ridge, olfactory groove and juxtasellar), 34 (31.2%) in zone II (clinoidal and CS), 5 (4.6%) in zone III (Meckel's cave and incisura), 28 (25.7%) in zone IV (petroclival);

Combined Open Approaches-III

AUTHORS	APPROACH	OUTCOME	CLINICAL DETAILS
			- 102/109 patients were stable at FU; - 3/109 deteriorated postoperatively; - 1/109 died for tumor progression (WHO grade III meningioma); - 14/109 (12.8%) pts presented new-onset postoperative CN deficits; - 14/109 (12.8%) pts suffered recurrence; 6/14 underwent further surgery, 4/14 underwent Gamma Knife RT, 4/14 managed conservatively;
Fernandez-Miranda et al.	Combined Hakuba-Kawase-Dolenc	STR	Complex spheno-cavernous-tentorial meningioma. FTOA with extradural Hakuba technique, followed by petrosectomy (Kawase) and anterior clinoidectomy. Intradural Dolenc technique. Access to the posterior fossa from a supratentorial opening. Postoperative improvement of CN3 and CN6; adjuvant GK RT.

Combined Open-Endoscopic Approaches

AUTHORS	APPROACH	SAMPLE	CLINICAL DETAILS
Noiphitak et al.	Combined endoscopic lateral TONES and lateral rim osteotomy	Anatomic study on 7 cadaveric heads	Enhanced CS visualization and improved surgical maneuverability in the area
Matsuo et al.	Translateral orbital wall approach with possible endoscopic assistance	Anatomic study	Increased access to CS and orbital apex particularly around the anterior clinoid process

Concluding Remarks

- CSM are rare pathologies that can cause significant neurological morbidity
- Histology, growth pattern and anatomical relationships dictate a clinical VS surgical management
- A plethora of techniques compose the surgical armamentarium against CSM
- Current literature entails a majority of case reports and anatomic studies, with minor instances of case series
- Future efforts should implement the techniques in the literature on larger patient samples

References

- Chotai et al., Review of Surgical Anatomy of the Tumors Involving Cavernous Sinus, *Asian J Neurosurgery*, 2018 Jan-Mar;13(1):1-8. https://doi.org/10.4103/ajns.AJNS_26_16
- Corniola et al., Management of cavernous sinus meningiomas: Consensus statement on behalf of the EANS skull base section, *Brain and Spine*, 2022 Jan 21:2:100864. https://doi.org/10.1016/j.bas.2022.100864
- Benjamin et al. Volumetric growth rates of untreated cavernous sinus meningiomas. *Journal of Neurosurgery,* 2021 Vol 136. 2022:749-75.6 https://doi.org/10.3171/2021.2.JNS203485
- Corvino et al., A New Perspective on the Cavernous Sinus as seen through multiple Surgical Corridors: Anatomical Study Comparing the Transorbital, Endonasal, and Transcranial Routes and the Relative Coterminous Spatial Regions, *Brain Sciences*, 2023 Aug 17;13(8):1215. https://doi.org/10.3390/brainsci13081215
- Dolenc, V., 1983. Direct microsurgical repair of intracavernous vascular lesions. J. Neurosurg. 58, 824–831. https://doi.org/10.3171/jns.1983.58.6.0824
- Hakuba, A., Nishimura, S., Shirakata, S., Tsukamoto, M., 1982. [Surgical approaches to the cavernous sinus. Report of 19 cases (author's transl)]. Neurol. Med.-Chir. 22, 295–308. https://doi.org/10.2176/nmc.22.295
- Kawase, T., Shiobara, R., Toya, S., 1991. Anterior transpetrosal-transtentorial approach for sphenopetroclival meningiomas: surgical method and results in 10 patients. Neurosurgery 28, 869–875.
- Zhao et al., Comparison of Dolenc and pterional approach in the microsurgery for blood blister-like aneurysms (BBAs) of internal carotid artery, J Clin Neurosci, 61 (2019) 142–146. https://doi.org/10.1016/j.jocn.2018.10.105
- Jean WC, Tai AX. Commentary: Resection of Cavernous Sinus Meningioma via Lateral Orbitotomy Approach: 2-Dimensional Operative Video. *Oper Neurosurg*. 2020;18(5):E165-E166. https://doi.org/10.1093/ons/opz210/5533075
- Vural et al., Transorbital endoscopic approaches to the skull base: a systematic literature review and anatomical description, *Neurosurgical Review* (2021) 44:2857–2878. https://doi.org/10.1007/s10143-020-01470-5
- Moe et al., Transorbital Neuroendoscopic Surgery, *Oper Neurosurg* 2010 Sep;67 (3 Suppl Operative):ons16 28. https://doi.org/10.1227/01.NEU.0000373431.08464.43
- Elshamy et al. Combined Transcavernous and Kawase's Approach for Gross Total Resection of a Cavernous Sinus Meningioma. 2021 Apr 8;83(Suppl 3):e603-e605. https://doi.org/10.1055/s-0041-1725025

References

- Nonaka et al., Gross Total Resection of a Recurrent Cavernous Sinus Meningioma through a Combined Transzygomatic Transcavernous and Extended Middle Fossa Approach with Cavernous Carotid Denudation *J Neurol Surg B Skull Base*, 2021 May 3;83(Suppl 3):e627-e629. https://doi.org/10.1055/s-0041-1727147 .
- Nonaka et al., Gross Total Resection of a Recurrent in-and-around Cavernous Sinus Meningioma through a Combined Transcavernous Anterior and Middle Infratemporal Fossa Approach with Extracranial-Intracranial Bypass 2021 Mar 18; 83(Suppl 3):e608-e609. https://doi.org/10.1055/s-0041-1725935
- Sabit et al. Extradural extranasal combined transmaxillary transsphenoidal approach to the cavernous sinus: a minimally invasive microsurgical model *Layngoscope* 2000 Feb;110(2 Pt 1):286-91. https://doi.org/10.1097/00005537-200002010-00019
- Morisako et al. Safe maximal resection of primary cavernous sinus meningiomas via a minimal anterior and posterior combined transpetrosal approach . *Neurosurgical Focus,* 2018 Apr;44(4):E11. https://doi.org/10.3171/2018.1.FOCUS17703
- Fong et al. Combined Anterior (Kawase) and Posterior Petrosectomy (pre-sigmoid/ retro-labyrinthine) for Resection of Post-Radiosurgery Recurrent Cavernous Sinus and Meckel's cave Meningioma; with Simultaneous Microvascular Decompression for Trigeminal Neuralgia: 2 Dimensional Operative video, and Review of Literature 2023 Apr:110:1-3. https://doi.org/10.1016/j.jocn.2023.02.002
- Sun et al., Surgical Management of Tumors Involving Meckel's Cave and Cavernous Sinus: Role of an Extended Middle Fossa and Lateral Sphenoidectomy Approach *Otol & Neurotol*, 2018 Jan;39(1):82-91. https://doi.org/10.1097/MAO.0000000000001602
- Aboud et al., Two-Stage Double Petrosal Approach for the Total Resection of Petroclival-Cavernous Meningioma: 2-Dimensional Operative Video, Oper Neurosurg (Hagerstown), 2021 Jun 15;21(1):E30-E31. https://doi.org/10.1093/ons/opab049
- Fukushima et al., Extradural Total Petrous Apex Resection with Trigeminal Translocation for Improved Exposure of the Posterior Cavernous Sinus and Petroclival Region, *Skull Base Surgery*, Volume 6, Number 2, April 1996
- Fernandez-Miranda et al., Extended Middle Fossa Approach With Anterior Petrosectomy and Anterior Clinoidectomy for Resection of Spheno-Cavernous-Tentorial Meningioma: The Hakuba-Kawase-Dolenc Approach: 3-Dimensional Operative Video. Oper Neurosurg (Hagerstown) 2017 Apr 1;13(2):281. https://doi.org/10.1093/ons/opw019
- Noiphithak et al., Comparative Analysis of the Exposure and Surgical Freedom of the Endoscopic Extended Minipterional Craniotomy and the Transorbital Endoscopic Approach to the Anterior and Middle Cranial Fossae *Operative Neurosurgery* 2019. 17 (2): 174–81. https://doi.org/10.1093/ons/opy309

References

- Matsuo et al., Translateral Orbital Wall Approach to the Orbit and Cavernous Sinus: Anatomic Study *Operative Neurosurgery* 2016. 12 (4): 360–73. https://doi.org/10.1227/NEU.0000000000001145
- Li et al., Expanded exposure and detailed anatomic analysis of the superior orbital fissure: implications for endonasal and transorbital approaches. Head Neck, 2020,42:3089–3097. https://doi.org/10.1002/hed.26399
- Taussky et al., Endocrinological outcome after pituitary transposition (hypophysopexy) and adjuvant radiotherapy for tumors involving the cavernous sinus: Clinical article. *J Neurosurg*. 2011; 115(1):55-62. https://doi.org/10.3171/2011.2.JNS10566

Thank you

Paolo Alimonti, MD[1] and Lucia Zamorano, MD,FAANOS,FICS[2]

1. Postdoctoral Research Fellow, Department of Neurosurgery, Brigham and Women's Hospital, Harvard Medical School, Boston, MA
2. Professor of Neurosurgery William Beaumont Oakland University School of Medicine

Graphic Illustrations: Emerson De Fazio

MD Candidate, Vita-Salute San Raffaele School of Medicine, Milan (MI), Italy

MICHIGAN BRAIN & SPINE SURGERY CENTER