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Retrosigmoid Craniectomy with a Layered Soft Tissue Dissection and Hydroxyapatite Reconstruction: Technical Note, Surgical Video, Regional Anatomy, and Outcomes

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Abstract

Introduction There are many reported modifications to the retrosigmoid approach including variations in skin incisions, soft tissue dissection, bone removal/replacement, and closure.

Objective The aim of this study was to report the technical nuances developed by two senior skull base surgeons for retrosigmoid craniectomy with reconstruction and provide anatomic dissections, surgical video, and outcomes.

Methods The regional soft tissue and bony anatomy as well as the steps for our retrosigmoid craniectomy were recorded with photographs, anatomic dissections, and video. Records from 2017 to 2019 were reviewed to determine the incidence of complications after the authors began using the described approach.

Results Dissections of the relevant soft tissue, vascular, and bony structures were performed. Key surgical steps are (1) a retroauricular C-shaped skin incision, (2) developing a skin and subgaleal tissue flap of equal thickness above the fascia over the temporalis and sub-occipital muscles, (3) creation of subperiosteal soft tissue planes over the top of the mastoid and along the superior nuchal line to expose the suboccipital region, (4) closure of the craniectomy defect with in-lay titanium mesh and overlay hydroxyapatite cranioplasty, and (5) reapproximation of the soft tissue edges during closure. Complications in 40 cases were pseudomeningocele requiring shunt ($n = 3$, 7.5%), wound infection ($n = 1$, 2.5%), and aseptic meningitis ($n = 1$, 2.5%). There were no incisional cerebrospinal fluid leaks.

Conclusion The relevant regional anatomy and a revised technique for retrosigmoid craniectomy with reconstruction have been presented with acceptable results. Readers can consider this technique when using the retrosigmoid approach for pathology in the cerebellopontine angle.

Keywords
- retrosigmoid
- cerebellopontine angle
- anatomy
- neuroanatomy
- CSF leak
- suboccipital
- retromastoid
- hydroxyapatite
- reconstruction

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Introduction

The retrosigmoid craniectomy is a standard approach to a variety of cerebellopontine angle (CPA) pathologies.[1] A variety of methods have been described for the approach including skin incisions, craniectomy versus craniotomy, dural closure, and bone repair/cranioplasty.[2–12] The anatomy of the bony, vascular, and neural anatomy is well described; however, many neurosurgeons are not familiar with the soft tissue anatomy of the retroauricular region. In most approaches, the superficial and deep muscles that attach to the squamous region of the occipital bone and the mastoid portion of the temporal bone are retracted forward over the mastoid by dividing the superior fibers of the musculature. However, a more anatomic method involves disinserting the muscle attachments from the mastoid process, the superior nuchal line and digastric groove in the sub-periosteal plane, and retracting the muscle inferiorly. This method avoids division of muscle fibers, respects the distribution of regional neurovascular structures, and may reduce postoperative muscle atrophy and improve cosmesis.

The senior authors (M.W.M, C.B.H.) have used similar methods for the approach and closure and have found the techniques to reduce cerebrospinal fluid (CSF) leaks and provide an excellent cosmetic result. Herein, we describe the technique with additional review of the anatomy and dissections demonstrating the subcutaneous and fascial planes in the region.

Materials and Methods

Surgical Technique

The patient is positioned supine and the ipsilateral shoulder is bolstered with a 1-L intravenous saline bag wrapped in thin foam. The patients head is rotated 70 to 80 degrees to the opposite side and placed in pin fixation. Registration of imaging to physical space is done using an image guided surgical navigation system if needed. A C-shaped skin incision (►**Video 1**) is planned by palpating the mastoid tip and outlining this with a V-shaped skin mark. At the superior end of the incision, a point is marked one finger breadth above the middle of the pinna and then a curvilinear incision is marked. The area is prepped and draped and the incision infiltrated with lidocaine 1% with epinephrine. The skin is incised over the region of the temporalis muscle and the subgaleal plane identified. Below the superior nuchal line, the galeal becomes the invested in suboccipital fascia. The skin incision is continued toward the mastoid tip making sure to incise the dermis through to the subcutaneous fat. Returning to the region over the temporalis fascia in the subgaleal plane, electrocautery is used to develop a subcutaneous plane for the skin flap that is the same thickness as the portion of the flap where galea is clearly visible. Care should be taken to look for the lesser occipital nerve at the 4 o'clock position on the incision in the subcutaneous tissue and to preserve this if at all possible. The skin flap is elevated above the fascia of the sternomastoid muscle and pericranium over the back of the mastoid.

Video 1

Retrosigmoid craniectomy and reconstruction technique. Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0040-1721815.

Once the skin flap is retracted forward, the superior nuchal line is marked out in the horizontal plane. At the posterior/medial end, a short inferior fascial cut is made to assist with retraction of the muscle flap inferiorly. Then a vertical fascial and periosteal incision is marked form the mastoid tip to the top of the exposure near the base of the skin flap. Blunt subperiosteal dissection is used to reflect the soft tissues forward and expose the mastoid process. The triangular fascial flap above the superior nuchal line is dissected in an anterior–inferior to posterior–superior direction and sutured to surrounding drapes. Then the suboccipital muscles are dissected from an superior–lateral to posterior–medial direction over the occipital bone and the digastric groove exposing the asterion, emissary vein, and suboccipital bone. The muscle can be retracted with scalp hooks or sutured to the drapes to maintain stretch on the muscle flap, which can help when closing the periosteal and muscle flaps at the end of the case.

The craniectomy is begun by placing a burr hole below and posterior to the emissary vein orifice and elevated a small bone flap. The craniectomy is then carried superiorly to expose the inferior edge of the transverse sinus and then forward using the emissary vein as a guide the transverse–sigmoid junction. Once this region is reached above the insertion of the emissary vein, then the back of the mastoid is drilled out from superior to inferior and the posterior edge of the sigmoid sinus identified. The inferior bony removal extends toward but not into the foramen magnum. Mastoid air cells are sealed with absorbable bone wax.

The posterior fossa dura is first opened with a linear vertical incision toward the cisterna magna and CSF is drained. The dura is opened in a standard manner and the CPA microdissection proceeds.

For closure a dural xenograft is frequently required and is sutured in place with 4–0 braided nylon suture (Nurolon, Johnson & Johnson, New Brunswick, New Jersey, United States). The dural closure is augmented with dural sealant (Adherus, Stryker, Kalamazoo, Michigan, United States). The craniectomy site is then covered with titanium mesh with the edges bent up along the anterior, superior, and posterior sides so the mesh is at the same level as the inner table of the skull. The mesh can be screwed into the diploic space along the anterior, superior, and posterior sides to secure it in place, where it can function as a basket for the hydroxyapatite cement. Then hydroxyapatite bone substitute (Hydroset, Stryker, Kalamazoo, Michigan, United States) is used to reconstruct the bony defect by placing the material on in layers and gradually building up the shape of the suboccipital bone and superior nuchal line as recommended by one of the senior authors (C.B.H.). The cement is suppled either premixed or as a powder along with the reacting solution. The cement is mixed to a consistency similar to a milkshake, and then loaded into the applicator syringe. It is applied to the mesh using the provided 2 to 3 mm barrel attachment, which allows it to be applied in thin layers and built up to the desired thickness. While using the applicator syringe is not necessary, it is the preferred method by the authors as it facilitates convenient layering of the cement, which allows the cement to harden slightly with each layer, making it less likely to pass through the mesh. Once hardened it can be sanded down using a Bovie scratch pad and continuous irrigation. The cranioplasty site is irrigated with 3% betadine solution, followed by saline, and 500 mg vancomycin powder is sprinkled over the cranioplasty site. The two fascial incisions are then closed with interrupted sutured technique using 2–0 absorbable suture (Vicryl, Johnson & Johnson, New Brunswick, New Jersey, United States). The skin flap is turned down over the repair and the subcutaneous tissue and galeal closed with a running 2–0 absorbable stitch (Vicryl, Johnson & Johnson, New Brunswick, New Jersey, United States) and the skin with 4–0 monofilament nylon (Novafil, Medtronic, Dublin, Ireland). The steps in the exposure and closure are demonstrated in ►**Video 1**.

Soft Tissue Anatomy—Bone and Muscles

The retroauricular region is an area in which different muscular and neurovascular anatomy converge. Therefore, surgical planning of the skin incision and soft tissue dissection is mandatory to avoid skin ischemia, muscle atrophy, or dysesthesias after performing a retrosigmoid approach.

Similar to the rest of the skull, the retroauricular scalp is made up of skin, subcutaneous tissue, and the galea aponeurosis. The vessels and nerves are found at the lower surface of the subcutaneous adipose tissue. The galea or aponeurotic compartment incorporates the dorsal connection of the frontalis muscle anteriorly and the occipitalis muscle posteriorly; these muscles are attached deep in the dermis and are usually not commonly seen during neurosurgical approaches. The occipitalis muscle joins the galea at the highest nuchal line and continues inferiorly attaching to the superior nuchal line and the mastoid (►**Fig. 1**). Lateral to the superior temporal line, the galea extends as the temporoparietal fascia, which directly overlies the loose areolar plane and superficial musculature of the area. Resembling the inferior extension of the fascia of the temporal region to the parotidomasseteric fascia, the parietal portion of the fascia continues inferiorly investing into the fascia of the auricular cartilage and the sternocleidomastoid muscle (SCM).[13]

Superior to the pinna and lying over the posterior portion of the temporalis muscle and temporoparietal fascia, the superior auricular muscle arises from the galea and attaches at the superior surface of the concha, which is the hollow just posterior to the external auditory canal. Posteriorly, on the same plane, the posterior auricular muscle arises from the mastoid at the level of the superior nuchal line and inserts anteriorly in the lower cranial surface of the concha (►**Fig. 2**).

The superficial, deep, and suboccipital cervical muscles can be found lying inferior to the superior nuchal line (►**Fig. 3**). The most superficial and prominent muscle found in this region is the mastoid portion of the SCM. Deeper and medial to the SCM, the splenius capitis inserts on the mastoid process at the lateral part of the superior nuchal line. The spinalis and semispinalis capitis insert between the superior and inferior nuchal lines lying under superior insertion of the trapezius muscle (►**Fig. 4**). The deep and lateral muscles of the suboccipital muscular group (rectus capitis posterior major and obliquus capitis superior) can be found attaching to the lateral inferior nuchal line. The posterior belly of the digastric muscle can be found attached to the digastric groove lateral to the suboccipital muscles.

Soft Tissue Anatomy—Neurovascular Structures

The retromastoid area contains the intersection of a vast network of anastomoses, with an inherent risk of injuring major extracranial arterial systems during the exposure. An understanding of the distribution of the regional angiosomes

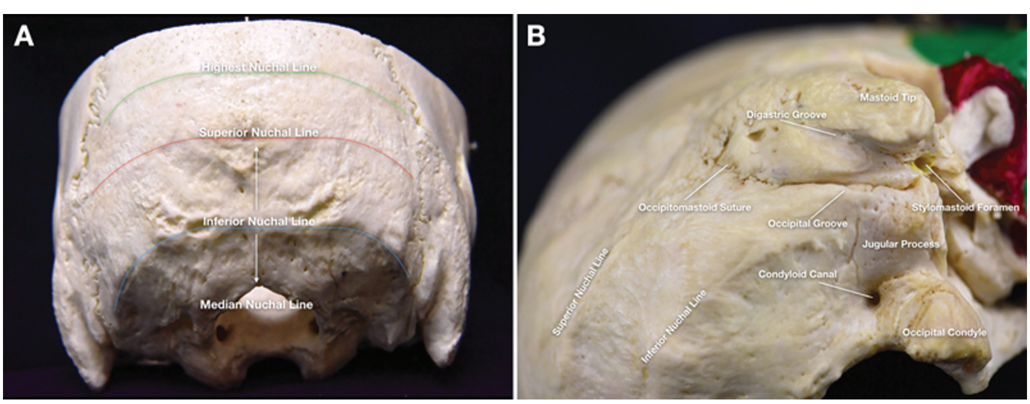

Fig. 1 Bony anatomy of the retrosigmoid approach. (**A**) Overview of the nuchal lines. The nuchal lines are prominences of the occipital bone that serve as attachments to dorsal cervical and occipital muscles. The height of the attachment is directly correlated to the superficiality of the layer that the muscle forms. (**B**) Inferior view of the occipitomastoid junction. The relevant prominences, grooves, and foramina of the region can be identified and serve as landmarks.

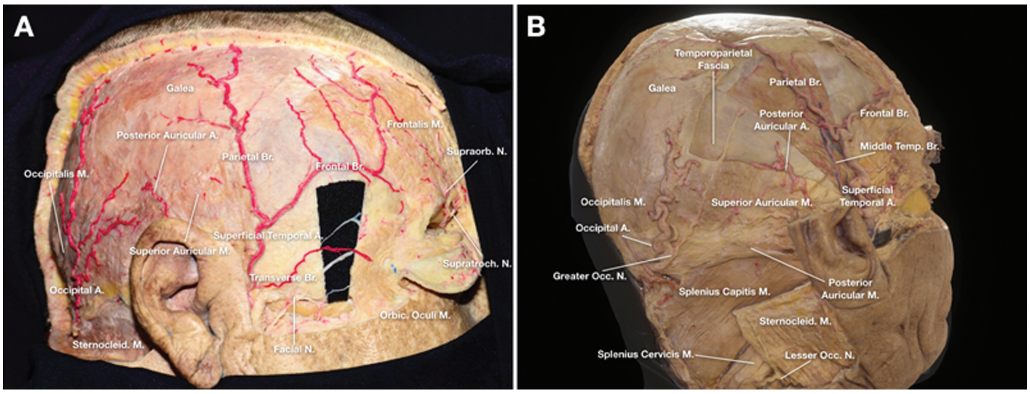

Fig. 2 Relevant myofascial structures. (**A**) Lateral view of the extracranial myofascial structures. The superficial extracranial musculature forms a system interconnected dorsally by the galea. The extracranial arteries can be seen running superficial during their trajectory toward the vertex. (**B**) Multilayer superficial exposure of the right periauricular region. This region receives arterial supply by the superficial temporal artery,

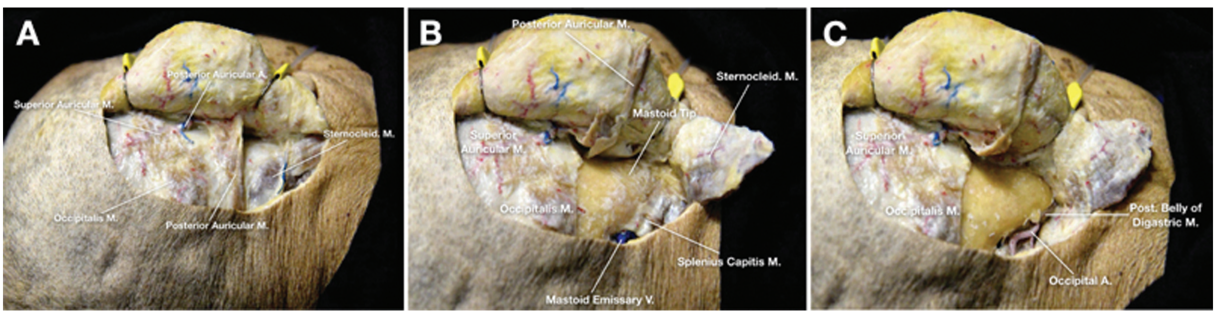

Fig. 3 Layers of the retrosigmoid approach. (**A**) Exposure of the superficial musculature of a retrosigmoid approach. The posterior auricular muscle can be identified running at the same axial level as the superior nuchal line. (**B**) Exposure of mastoid tip. After detaching the sternocleidomastoid muscle, the splenius capitis can be identified, attaching to the posteromedial surface of the mastoid tip. The occipital vein draining into the mastoid emissary vein can be identified. (**C**) Exposure of the occipital artery. The occipital artery can be seen exiting the occipital groove that lies medial to the insertion of the posterior belly of the digastric muscle.

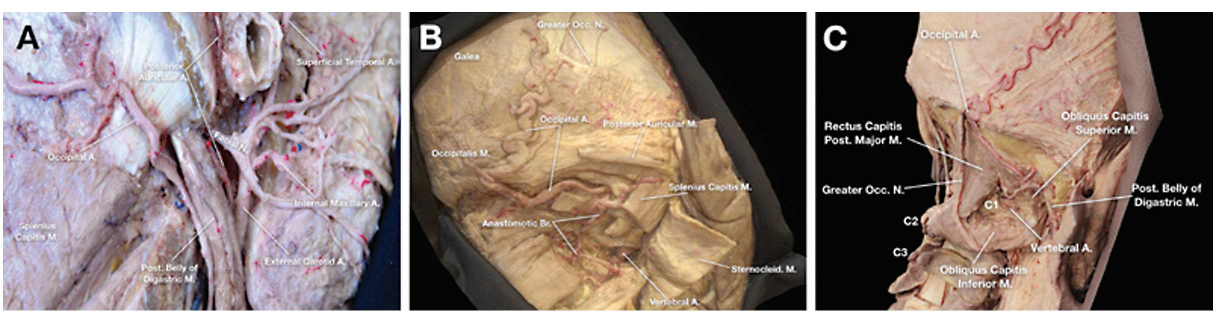

Fig. 4 Occipital artery course in the retrosigmoid region. (**A**) Right lateral view of the proximal occipital and posterior auricular arteries. The occipital artery arises from the external carotid artery, proximal to the posterior auricular artery running medial to the posterior belly of the digastric muscle giving off muscular and radicular branches. The posterior auricular artery travels vertically immediately posterior to the auricle; its proximal portion gives off branches to the facial nerve, parotid, and muscles of the region. (**B**) Posterior view of the muscular and galeal portion of the occipital artery. The ascending and descending muscular branches of the occipital muscle can be identified, forming an anastomotic network with muscular branches of the vertebral artery. (**C**) View of the suboccipital muscles in relation to the occipital artery course. The occipital artery courses over the obliquus capitis superior and the rectus capitis posterior major and pierces the semispinalis to becoming superficial running over the occipitalis muscle and galea.

is crucial for the preservation of the soft tissue flap.[14] The region is supplied superiorly by the superficial (i.e., parietal) and deep (i.e., middle temporal artery) branches of the superficial temporal artery (STA) and the posterior auricular artery (PAA) (►**Fig. 2**).[15] The PAA arises from the external carotid artery (►**Fig. 4**), distal to the occipital artery (OA), and courses from the mastoid tip and auricle (~1.2 cm posterior to the external auditory meatus) and runs almost vertically toward the vertex giving off three to five distal branches that supply the myofascial components of the

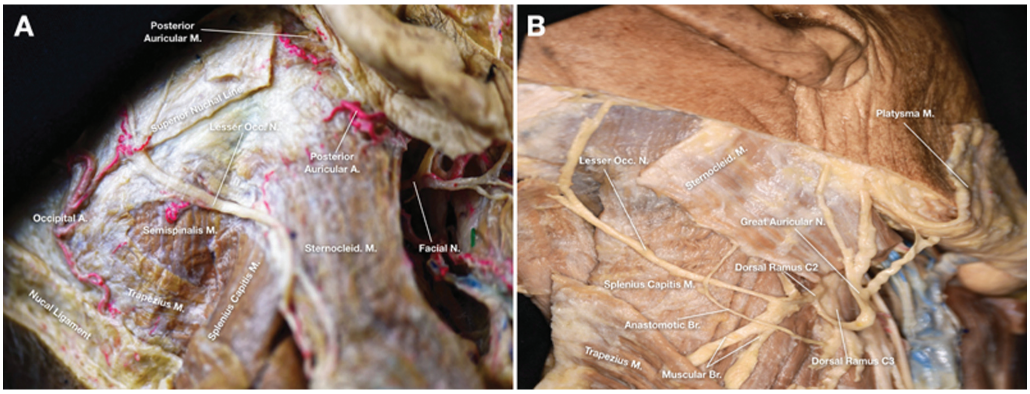

Fig. 5 Anatomy of superficial nerves in the retrosigmoid region. (**A**) View of the right lesser occipital nerve. The right lesser occipital nerve runs over the posterior border of the sternocleidomastoid muscle and innervates the superior half of the retroauricular region. (**B**) Posterolateral view of the main nerves related to the retroauricular region. The great auricular nerve runs anterior to the lesser occipital nerve and gives off branches directed to the parotidomasseteric region and the inferior half of the retroauricular region.

region forming anastomoses with the posterior branches of the STA and galeal branches of the OA.[16]

Inferior to the superior nuchal line, the main supply is performed by the OA, and anastomotic muscular branches to the vertebral artery (►**Figs. 2–4**). The OA trunk lies within the occipital groove, medial to the digastric groove. After emerging from the occipital groove, medial to the posterior belly of the digastric muscle and the splenius capitis muscle, the OA courses cranially and medial, passing posterior to the obliquus superioris and the semispinalis capitis, giving off ascending and descending muscular branches that form arcades with branches of the vertebral artery as well as transosseous branches that irrigate part of the posterior dura fossa (►**Fig. 4**). The OA reaches the superior nuchal line, where it pierces the insertion of the splenium capitis at $\sim$3.5 t o4 cm lateral to the inion.[17,18]

The venous drainage of the region is through the posterior auricular, occipital, and mastoid emissary veins that drain into a complex network of major extracranial veins (i.e., external and internal jugular veins), suboccipital and vertebral plexuses as well as intracranial sinuses (i.e., sigmoid, transverse sinus). Of particular interest for the retrosigmoid approach is the mastoid emissary vein (►**Fig. 3**), which can be found near the occipitomastoid suture and can be a source of copious bleeding or embolisms.

The sensory function of the retroauricular region is supplied by the great auricular nerve in the inferior half and the lesser occipital nerve in the superior half (►**Fig. 5**). The great auricular nerve arises from C2 and C3 and crosses the SCM lying superficial to the fascia. It subsequently reaches out the posterior auricular muscle at the superior nuchal line giving off terminal anastomotic branches. The lesser occipital nerve arises from the ventral ramus of C2 and curves lateral to the accessory nerve ascending along the posterior border of the SCM; it emerges posterior and superior to the great auricular nerve to travel superficially toward the superior half of the ear diverging in a fan-like fashion from the great auricular nerve creating anastomoses anteriorly with the great auricular nerve and medially with the greater occipital nerve. Care should be taken during the initial stages of the skin flap to preserve these nerves since they lie superficial to the fascia and pierce the subcutaneous plane at a variable level.[19]

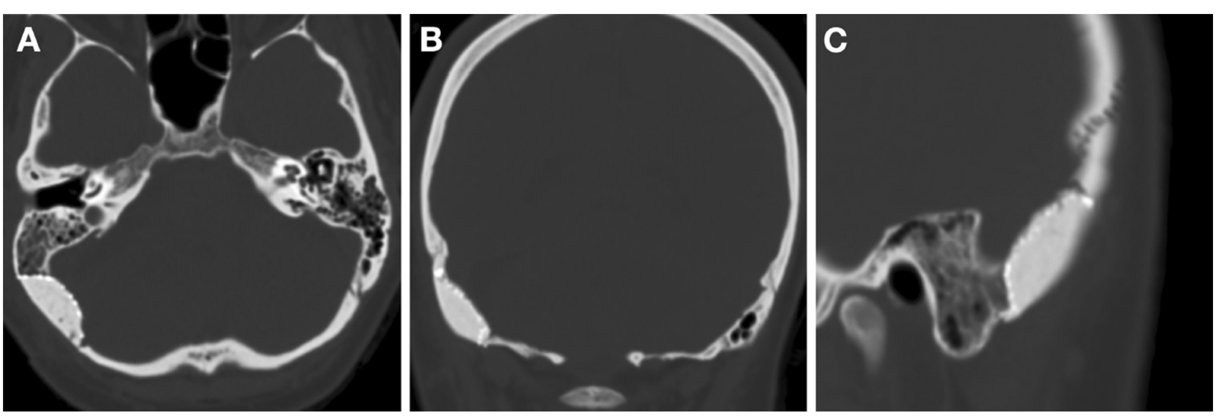

Fig. 6 Postoperative computed tomography showing mesh and hydroxyapatite reconstruction. (**A**) Axial, (**B**) coronal, and (**C**) sagittal bone window images showing mesh basket holding they hydroxyapatite cement.

Table 1 Retrosigmoid: technical note and video

Patient characteristics and operative results	# (%)
Patients (#)	40
Median age in years (range)	54 (29–82)
Female	34 (85)
Diagnosis	
Meningioma	17 (43)
Schwannoma	15 (38)
IgG4-related disease	2 (5)
Epidermoid cyst	1 (8)
Neuroenteric cyst	1 (3)
Craniopharyngioma	1 (3)
Metastatic carcinoma	1 (3)
Hemangioblastoma	1 (3)
Choroid plexus papilloma	1 (3)
Intraoperative CSF diversion	4 (10)
Lumbar subarachnoid drain	2 (5)
External ventricular drain	2 (5)
Outcomes	
Pseudomeningocele	4 (10)
Required ventriculoperitoneal shunt	3 (8)
Resolved with acetazolamide	1 (3)
Incisional CSF leak	0 (0)
CSF rhinorrhea	2 (5)
Required obliteration	2 (5)
Wound infection	1 (3)
Required wound washout	1 (3)
Aseptic meningitis	1 (3)

Abbreviations: IgG4, immunoglobulin G 4; CSF, cerebrospinal fluid.

Results

The described technique has been used for 40 cases by the senior author (M.W.M.) with good results (►**Table 1**). The reconstruction technique is best appreciated on a postoperative computed tomography, where the mesh functions as a basket to keep the hydroxyapatite cement at the level of the normal skull (►**Fig. 6**). In this series, there were four patients who developed pseudomeningoceles. One resolved with acetazolamide over the course of 6 weeks. Three patients required ventriculoperitoneal shunting. Two of the patients requiring ventriculoperitoneal shunting had hydrocephalus preoperatively from large vestibular schwannomas. The other patient that required a ventriculoperitoneal shunt had an epidermoid cyst that had been resected twice via the same sided retrosigmoid craniectomy. There were no cases of CSF leaking through the incision or wound breakdown. There were two cases of CSF rhinorrhea due to transmastoid CSF leak through the exposed air cells of the petrous bone into the eustachian tube, which both occurred after drilling the internal auditory canal for vestibular schwannoma resection and required inner ear obliteration. The leaks did not occur at the craniectomy site where the hydroxyapatite reconstruction was performed. Neither of these cases were associated with pseudomeningocele. There was one wound infection and one case of aseptic meningitis that responded to a short course of steroids. The cosmetic results are very good, and suboccipital muscle atrophy with retroauricular depressions is rare (►**Fig. 7**).

Discussion

The retrosigmoid approach is one of the most common approaches used for access to posterior fossa lesions and a basic skill for every neurosurgeon. Numerous variations and modifications of the approach have been described. We performed anatomic dissections of the regional anatomy and present a video and description of the method developed by the two senior authors (M.W.M. and C.B.H.) that we found to provide comparable results to prior series and also excellent cosmesis with minimal muscle atrophy.

Many incisions have been described for the retrosigmoid craniotomy. One of the original incisions described by Dandy and favored by others include the reverse "U" incision, with an inferiorly based flap.[11] Proponents of the reverse "U" incision feel that it decreases occipital headaches and allows excellent working angles. Others have argued for using shorter incisions and worked to make craniotomies as small as possible,[6] although we have not noticed a significant difference in patient outcomes when using these incisions.

There were no incisional CSF leaks in this series, and we only encountered pseudomeningoceles in patients with preoperative hydrocephalus or in the setting of redo surgery. This is in contrast to other studies with linear incisions and CSF leak rates up to 15%.[5] However, in general, smaller, more minimal openings are associated with decreased CSF leak rates and approach-related complications.[6,12] Smaller cranial openings can be augmented with the use of endoscopic assistance in experienced hands.[20,21]

Others have described similar handling of the muscular and soft tissue planes, but not combined with the hydroxyapatite reconstruction.[4] Those who have used hydroxyapatite reconstruction with different incisional and soft tissue management have also reported very low CSF leak rates.[7] Alternatives to hydroxyapatite include demineralized bone matrix,[8] although we prefer the bone cement because it creates an immediate barrier to leaks, while bone matrix is porous. Risks of using hydroxyapatite cement include infection and a theoretical risk of nerve injury, if it was to come in contact with a nerve. We did not observe an increase in infection rate after starting to use the cement. Finally, given that the dura is closed in a watertight manner prior to cement application, it is unlikely that any cement could contact any cranial nerves.

Limitations of the study include the smaller sample size, and the fact that we did not have information available characterizing postoperative headaches and postauricular pain, a known complication of the retrosigmoid approach. We had one case of a lesser occipital neuroma following a retrosigmoid craniotomy

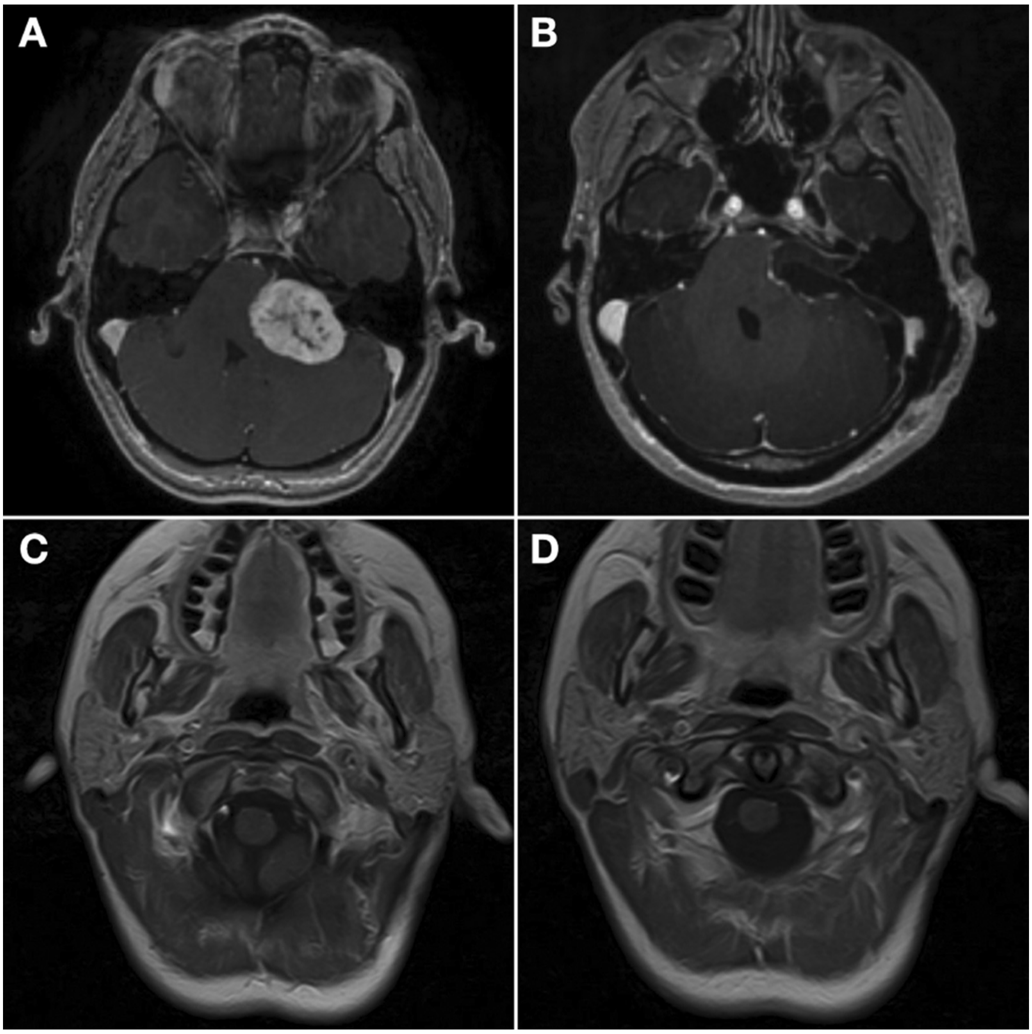

Fig. 7 Case example with preservation of suboccipital musculature. (**A**) Preoperative axial post-contrast T1-weighted magnetic resonance imaging (MRI) showing a large left vestibular schwannoma. (**B**) Postoperative axial MRI showing near total resection. (**C**) and **D**) Axial post-contrast T1 weighted MRI at 1 year postoperative showing excellent contouring of the skin and minimal atrophy of the suboccipital muscles using the retrosigmoid craniectomy and reconstruction technique described.

(prior to implementing the approach and reconstruction described here) that required re-exploration and excision 2 years postoperative for persistent sharp pain.[22] Lesser occipital nerve injury can cause significant patient distress, and appropriate steps should be taken to avoid the nerve if possible during incision, and if found, to protect it.

Conclusion

The retrosigmoid approach is one of the primary approaches used to access the posterior fossa and CPA. There are numerous skin incisions, bone openings, and reconstruction techniques that have been described in the literature. We have provided a surgical video, anatomic dissections of the regional anatomy, and operative outcomes for readers to consider as an option when performing a retrosigmoid approach. Each neurosurgeon must select the method that fits best with their comfort level and experience, and tailor it to each particular pathology to produce the best outcome for their patient.

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Conflict of Interest
None declared.

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