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TECHNICAL NOTE

Two-bone flap craniotomy for the transpetrosal–presigmoid approach to avoid a bony defect in the periauricular area after surgery on petroclival lesions: technical note

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Abstract The authors describe a two-bone-flap craniotomy technique to avoid the bone defect caused by the transpetrosal–presigmoid approach. Briefly, this technique includes three steps. The first step is to elevate a temporoparietal bone flap located superiorly to the transverse and sigmoid sinuses. The second step is to dissect the transverse and sigmoid sinuses away from the bone by inserting a gelatin sponge. This maneuver provides hemostasis and protects the sinuses from injury. The third step is to cut a second bone flap including part of the temporal bone and the outer table of the mastoid bone with a high-speed drill system. After the operation, the two bone flaps are fixed in place with titanium osteosynthesis fixation material. This approach provides a simple, easy, and safe technique for the transpetrosal–presigmoid approach. The technique has been performed in 83 patients treated for petroclival neoplasms with excellent cosmetic results.

Keywords Two-bone flap craniectomy · Petroclival meningioma · Petrosal approach · Presigmoid approach

Introduction

Meningiomas arising from the apical petrous bone and clivus were once considered inoperable [1]. The introduction of microsurgical techniques and the transpetrosal approach have made this pathological entity curable [2–5]. Now, the transpetrosal–presigmoid approach is widely used for the surgery of petroclival tumors, producing relatively lower morbidity and mortality rates [2, 5–7]. Mastoidectomy or removal of petrous bone is exhausting and time-consuming work, which, without exception, results in a large bone defect in the mastoid area after surgery. Traditionally, a fatty graft and/or a part of the temporal muscle have been used to fill the mastoid area and the bone defect; however, the fat or muscle graft progressively shrinks, resulting in a permanent deformity in the retroauricular area. This bone defect is a source of discomfort and cosmetic concern. To avoid this bony defect, we have developed an osteoplastic craniotomy technique for use with the transpetrosal–presigmoid approach.

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Patients

From July 2003 to July 2006, 83 patients with petroclival meningioma were treated with the transpetrosal–presigmoid approach. This cohort consisted of 34 men and 49 women, aged 28–67 years (average 47.2 years). The course of disease ranged from 1 to 244 months (average 38.2 months). With regards to presenting symptoms, 30 of the patients had facial numbness, 21 had headache, 12 had diplopia, seven experienced ataxia, five reported decreased hearing, five had hemiparesis, two exhibited a decreased gag reflex, and one patient experienced blurred vision. Tumor size varied from 3 to 7 cm (average 4.7 cm) according to magnetic resonance imaging. All patients were followed up from 13 to 47 months by neuroradiological and neurological examinations.

Surgical technique

Patient positioning

The patient is placed in the lateral decubitus position. The patient's head is slightly inclined towards the floor and turned backwards so that the temporal lobe and cerebellar hemisphere will fall away from the petrous ridge. The head is then fixed in a three-point Mayfield head holder.

Skin flap

A question-mark/reverse question-mark skin incision is begun 0.5 cm above the zygoma to avoid injury to the temporal branch of the facial nerve and continued such that it circles above the ear; the incision then descends 1 cm behind the mastoid process. The skin flap is elevated and then retracted anteriorly and inferiorly. The temporal muscle and the pericranium are also elevated and retracted in the same fashion. The sternomastoid muscle is left intact. Thus, the bony surfaces of the temporal bone, mastoid, and lateral posterior fossa are exposed.

Craniotomy procedure

Two-bone-flap craniotomy is performed. This procedure can be divided into three steps. The first step is to elevate a temporoparietal bone flap that is located superiorly to the transverse sinus (TS) and the sigmoid sinus (SS). Usually, a single burr hole is sufficient. The burr hole is placed at the crossing point of the supramastoid crest and parietomastoid suture (Fig. 1). This point is located just superior to the junction of the TS and SS such that the margin of that junction can be exposed. If the margin of the junction of TS and SS is not apparent, the burr hole can be enlarged until the junction is exposed. The dura in the burr hole is dissected with a curved probe. The temporal bone and a part of the parietal bone are then cut as shown in Fig. 2, leaving a narrow piece of temporal bone approximately 1-cm wide attached to the mastoid bone. This narrow portion of temporal bone facilitates the eventual fixation of the two bone flaps. Furthermore, as the dura is often firmly attached to the bone near the skull base area, leaving a narrow bone portion around this area allows the dura to be dissected from the bone before it is cut, thus reducing the possibility of dural laceration. The dura in elderly patients or patients who have large benign lesions might be firmly attached to the bone; therefore, a four-burr-hole craniotomy is safer in these patients to avoid dural laceration.

The second step is to dissect the TS and SS away from the inner table of the mastoid and occipital bone. This dissection can be performed by inserting a gelatin sponge extradurally (Fig. 2). The sponge compresses and separates the sinus away from the bone. The gelatin sponge cushion should be at least 2-mm thick and large enough such that it provides hemostasis and protects the sinuses from injury when the second bone flap is cut.

The third step is to elevate the second (temporomastoidoccipital) bone flap. Milling is used to cut the bone at the bottom of the bone flap on both sides towards the petrous ridge, stopping upon reaching it. Next, the junction part of the petrous bone (the petrous ridge) is drilled extradurally. Then, the second bone flap is elevated (Fig. 3). The

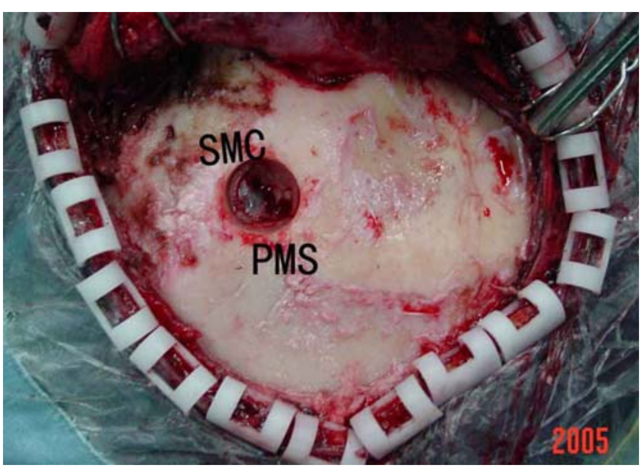

Fig. 1 The keyhole was drilled slightly below the crossing point of the supramastoid crest and parietomastoid suture so that the margin of the junction of TS and SS could be exposed. *SMC* supramastoid crest, *PSC* parietomastoid suture

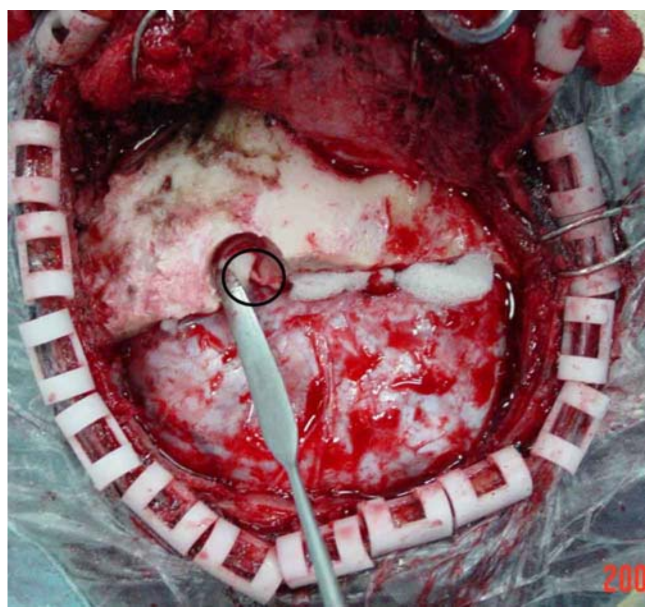

Fig. 2 The first bone flap was elevated. The temporal bone and a portion of the parietal bone were cut, leaving a narrow temporal bone fragment approximately 1-cm wide. The sponge protects the sinuses from injury when the second bone flap is cut. The *black circle* is the junction of TS and SS

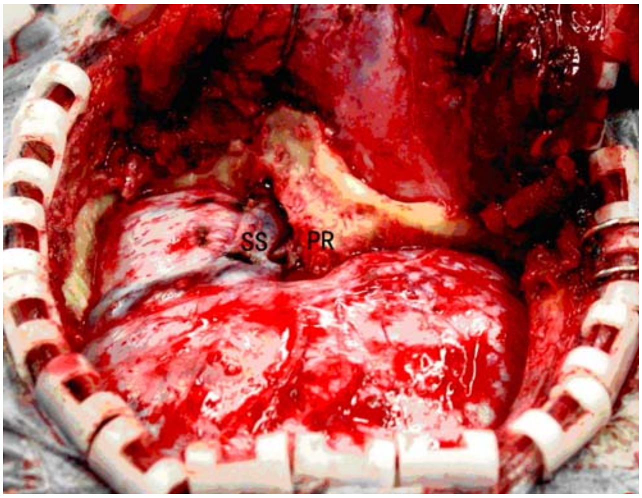

Fig. 3 The second bone flap was elevated. The second bone flap was cut with the high-speed drill system. After the second bone flap was elevated, the sinus was left intact. *SS* sigmoid sinus, *PR* petrous ridge

remaining portion of the petrous bone is then removed with a high-speed drill to expose a 20×10 mm area of the presigmoid dura, just lateral to the posterior semicircular canal (Fig. 4). Two key considerations are required to protect the posterior semicircular canal. First, it is necessary to identify the arcuate eminence, as the superior semicircular canal is located 2 mm underneath the top of this landmark. Thus, high-speed drilling near the arcuate eminence must be carefully performed. Second, attention must be paid to the change in bone density near the semicircular canal, which is marked by a switch from cancellous to cortical bone. If a change in bone density is perceived, drilling should be immediately halted. The tip of the mastoid process with the origin of the sternocleidomastoid muscle is left intact. The opened air cells are obliterated with bone wax.

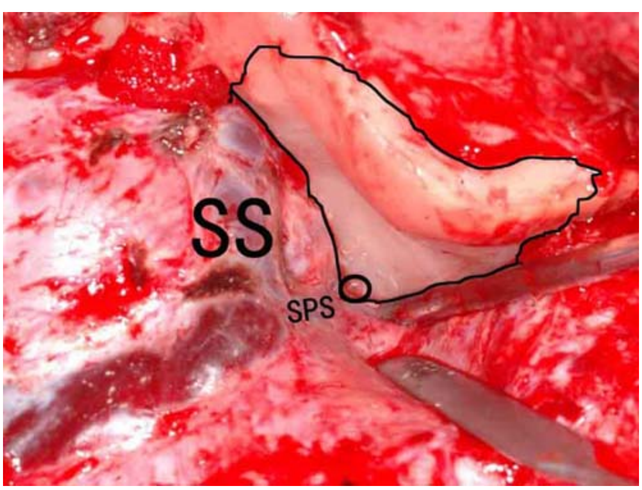

Fig. 4 The presigmoid dura was exposed. The petrous ridge was removed with a high-speed drill to expose a 20×10-mm area of the presigmoid dura. The opened air cells had already been obliterated with bone wax. *SS* sigmoid sinus, *SPS* superior petrosal sinus. The *black circle* is the location of the arcuate eminence. *Black lines* mark the drilled region

Dural opening and closure

The posterior fossa dura is opened along the anterior margin of the SS. The incision is then extended up toward a supratentorial dural incision made on the floor of the temporal fossa. The superior petrosal sinus is ligated and transected. A bipolar coagulator should not be used during this maneuver so that a watertight closure of the dura can be performed using a graft.

After closure of the dura mater, the two bone flaps are fixed in place with titanium osteosynthesis fixation material (Fig. 5).

Results

During the past 4 years, we have routinely used this modified osteoplastic craniotomy for the transpetrosal–presigmoid approach. A total of 83 patients were treated using this method, with only six sinus wall tears and one wound infection observed as a result. Computed tomographic (CT) scans (Fig. 6) obtained 2 weeks postoperatively showed that bone defects only existed along the cut line. No deformity in the operative area was found in our patients. Post-operative skull base CT using 1-mm slices revealed the circular canals to be intact after the procedure (Fig. 7).

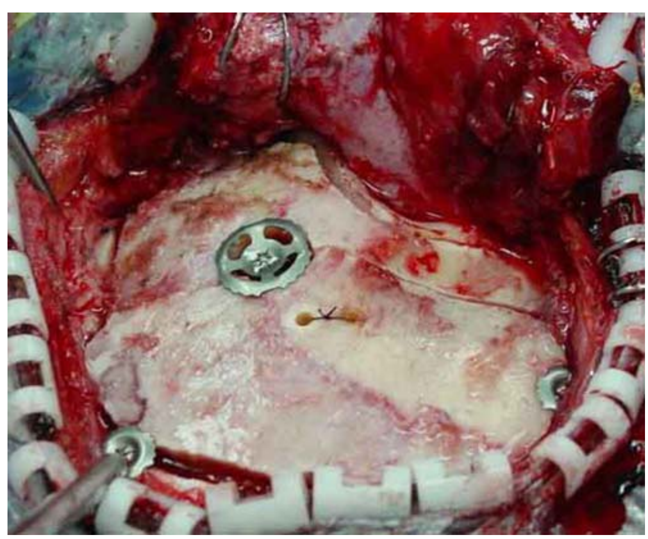

Fig. 5 The two bone flaps were fixed in place with titanium osteosynthesis fixation material

Fig. 6 A CT scan showing bone reconstruction. The CT scan was obtained 2 weeks postoperatively and showed that a bone defect only exists along the cut line

Discussion

The petrosal approach provides several advantages including minimal retraction of the cerebellum and temporal lobes, a shorter operative distance to the clivus, and a direct line of sight to the anterior and lateral aspects of the brain stem. This approach has become the first choice for surgery of petroclival lesions [2, 3, 5–12]. However, this approach is also characterized by the conflicting goals of resecting enough petrous bone to sufficiently expose the tissue while still protecting the essential structures in that area. Our craniotomy approach creates a hole smaller than others reported in the literature and is performed more laterally. Also, our approach does not expose structures below the skull base and utilizes extreme caution when nearing structures such as the semicircular canal.

Another goal of neurosurgeons when dealing with clivus meningiomas is to minimize the craniotomy defect caused by mastoidectomy. Hakuba et al. described the use of radical mastoidectomy, which includes the roof of the internal auditory meatus, to create enough exposure for access to clivus meningiomas [13]. However, mastoidectomy often results in a large bone defect after surgery, even with fatty graft placement. Couldwell and Fukushima [14] described a cosmetic technique for mastoidectomy; however, this technique can result in SS laceration. Sasaki et al. [15] described an en bloc petrosectomy that is cosmetic but presents a danger of injury to the facial nerve, labyrinth, or SS in some cases. Tokoro et al. [16] have suggested a simple technique for reconstructing mastoidectomy defects by cutting the mastoid bone with a rongeur and reinserting the bone chips. Spetzler et al. [17] and Sawamura and deTrilobet [18] utilize a similar approach involving an osteoplastic mastoidectomy followed by a single-flap temporo-suboccipital craniotomy so that bone defects can be prevented. However, placing mastoid bone chips back into defects raises concerns of infection and mucocele formation. More importantly, the use of mastoidectomy as a first step makes the procedure more complicated and increases the unpredictability of the bone resection.

To overcome these reported shortcomings, we modified the osteoplastic craniotomy. There are several advantages to this modified technique. Because there is no sinus under the first bone flap area, we can elevate the flap quickly and safely. After the first bone flap has been removed, the sinuses and the dura in the sinus region can be dissected away from the bone with maximal safety, reducing the risk of sinus injury. Thus, blood loss is greatly decreased using this technique. Because there are always bridge veins near the junction of the TS and SS, dissection around this area often results in vigorous bleeding or sinus wall laceration. The gelatin sponge cushion used in our technique provides hemostasis and protection of the sinuses from injury when the second bone flap is made. Even if the sinus wall is lacerated, the bleeding can be

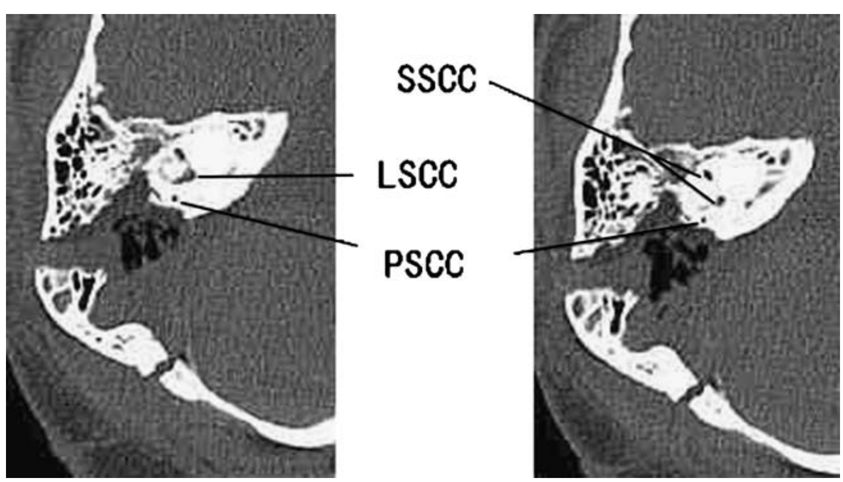

Fig. 7 Postoperative skull base CT (bone window with 1-mm slices) reveals the semicircular canals to be in good anatomic condition. *SSCC* the superior semicircular canal, *LSCC* the lateral semicircular canal, *PSCC* posterior semicircular canal

controlled by compression of the sponge cushion before the flap is removed. After the flap is removed, bleeding is much more easily controlled under direct vision.As the dura is often attached firmly to the bone near the skull base, a narrow temporal bone piece left attached to the mastoid allows dissection between the dura and the bone, thus reducing dural lacerations when the second bone flap is cut. Furthermore, only one or two burr holes are needed, so the chance of a bone defect remaining after surgery is reduced. Finally, in addition to providing protection for the SS, this maneuver also reduces the operating time, including the creation of the skin flap, craniotomy, and mastoidectomy, from 3 to 4 h to less than 2 h.

In the past 4 years, a total of 83 patients underwent surgery with this modified osteoplastic craniotomy in our institution. Only six TS or SS lacerations occurred. Of the six lacerations, only one was longer than 1 cm and required sinus repair. The remaining five lacerations were from the mastoid emissary vein and were easily dealt with by compression of the gelatin sponge. The blood loss during craniectomy was usually less than 100 ml, which was much less than in those performed previous to the adoption of our modified technique. No fat or muscle graft was needed to fill the bony defect, thus avoiding another operation for harvesting of the fat graft, and the temporal muscle atrophy rate was also subsequently reduced.

Cranial radiographs and bone window CT scans obtained postoperatively showed almost no bony defect in the mastoid area and a good cosmetic result.

Some neurosurgeons advocate polymethyl methacrylate (PMMA) bone repair [19]. However, the benefit of using osteoclastic craniectomy is derived from being able to directly visualize the operative field. For example, when the first temporoparietal bone flap is elevated, the TS can be seen clearly, and the SS can be tracked under direct view. PMMA and other artificial materials are being used in cranioplasty; however, we prefer to use autologous bone grafts. In our view, autologous bone grafts could reduce the chance of any immune response to these materials.

Protection of the semicircular canal is challenging [20]. Identification of the arcuate eminence and detection of bone density changes are important for protection of structure. Furthermore, we are carrying out a neuronavigational clinical study, which we hope will provide a more precise guide to avoid crucial structures within the petrous bone.

Our technique allows the sigmoid sinus to remain intact when opening the dura. After drilling through part of the petrous bone, we only ligate and cut off the superior petrosal sinus even in the presence of large petroclival neoplasms. Another vessel at risk is the vein of Labbe and its drainage to the transverse sinus, specifically, in the presigmoid region, although the track that it takes varies anatomically. If we retract the temporal lobe gently, stretching and injury of this vein can be avoided.

To avoid creating potential gaps to the outside space, we use bone wax to close the cancellous mastoid bone. The defect cavity created is not very large, as we retain the lateral compact portion of the petrous bone and thus do not require additional materials to fill it.

Sinus or air cells open after craniotomy increase the risk of mucoceles [21]. We use bone wax to close mastoid air cells, and in our study, we report no mucoceles in any patients. However, we need to follow these patients for a longer period of time to confirm the utility of bone wax. PMMA is a new material that can close air cells and may decrease the occurrence of mucoceles, but further clinical study is required to prove its safety and practicality.

Conclusions

We have created a two-bone-flap craniotomy technique that can avoid the bone defect caused by the transpetrosal–presigmoid approach and decrease the incidence of injury to the SS and dura. Our technique emphasizes protection of important structures such as the semicircular canal, and it should be evaluated more extensively in further studies.

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Comments

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The authors have illustrated the technique of a modified osteoplastic craniotomy for the transpetrosal–presigmoid approach in the lines of similar work published earlier by Spetzler et al. and Sawamura et al. This work reinforces the earlier publications by adding the concept of two-bone-flap osteoplastic craniotomy, elucidating the bone removal by postoperative CT scans. The authors have described the advantages of removing the first bone flap area safely without risk of sinus injury as well as the use of muscle/fat graft to fill the bony defect. We use a similar technique, though we often find the use of a piece of titanium mesh over the fat defect to be equally efficacious. The authors have commented on the risk of injuring the posterior semicircular canal as well, and this cannot be understated. The article is a good addition to the existing body of neurosurgical literature on transpetrosal–presigmoid approaches.

Claudius Thomé, Mannheim, Germany

Dr. Guijun et al. describe an osteoplastic craniotomy technique for the transpetrosal approach, which is an interesting modification of Couldwell and Fukushima's technique [14]. In addition to the two-bone-flap craniotomy, well-established technical considerations for transpetrosal approaches are recapitulated.

Obviously, it is generally desirable to use autologous material for bony closure. Nevertheless, I am skeptical whether this modified approach is actually superior to a (partly) osteoclastic technique with an artificial flap. Many experts advocate an osteoclastic craniectomy and closure with PMMA for retrosigmoid approaches, since sinus injury can effectively be minimized. As vascular injuries can entail a significant morbidity, it is often not considered adequate to risk an osteoplastic craniotomy in these cases. This is particularly true in an elderly population that may be more common in Europe or North America. In the presented series, the 7% rate of sinus lacerations (six out of 83 patients) was fortunately not associated with significant sequelae. Another disadvantage of the proposed technique could be leaving mastoid air cells in the bone flap as depicted in Fig. 7, as this may provoke an infection or mucoceles.

Although transpetrosal surgery has evolved in recent decades as the standard approach for petroclival lesions, it has to be mentioned that modern combined treatment algorithms including surgery and radiosurgery or radiotherapy often employ (subtotal) resections via less invasive, e.g., retrosigmoid approaches. Regardless of these limitations, this technical note adds an appealing osteoplastic technique for transpetrosal approaches, and the authors are to be congratulated on a large clinical series of 83 patients demonstrating the technique's safety and favorable cosmesis.