




Keyhole Mini-Craniotomy Middle Fossa Approach for Tegmen Repair: A Case Series and Technical Instruction

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Abstract

Keywords

- ▶ cerebrospinal fluid leak
- ▶ keyhole craniotomy
- ▶ middle cranial fossa approach
- ▶ mini-craniotomy
- ▶ minimally invasive
- ▶ otorrhea
- ▶ tegmen defect

Background and Importance Tegmen defects associated with cerebrospinal fluid (CSF) leaks are a rare pathology that can result in severe complications if left untreated. There is no universal optimal surgical algorithm for repair, although the most common techniques are the middle fossa craniotomy (traditionally 25 cm² in area), the transmastoid approach, or both. Here, we describe successful use of a keyhole mini-craniotomy, only 6 cm² in area, without mastoidectomy or days of lumbar drainage.

Clinical Presentation Three patients presented with right-sided CSF otorrhea and hearing loss, with varying sizes of tegmen defects and associated encephaloceles. Keyhole craniotomies measuring 3 × 2 cm were used to perform a multilayer repair comprising an intradural collagen dural substitute, extradural fascial graft, extradural collagen dural substitute, fibrin sealant, and sometimes bony reconstruction using partial thickness craniotomy grafting. All patients were discharged on postoperative day 1 or 2, with no recurrence of symptoms at 6 months.

Conclusion The keyhole craniotomy approach does not sacrifice the extent of operative access for this pathology. This minimally invasive approach can likely be used more often without need for concomitant mastoidectomy, ultimately enabling shorter hospital stays and more rapid recovery.

Background and Importance

Tegmen defects with cerebrospinal fluid (CSF) leakage may be spontaneous or secondary to trauma, surgery, congenital abnormalities, tumors, idiopathic intracranial hypertension, or chronic ear disease and infection.^{1–6} Presentation includes conductive hearing loss, otitis media, imbalance, tinnitus, CSF otorrhea, and chronic headaches.^{1,4,7,8} For CSF leaks,

early operative treatment is important in avoiding serious complications (hearing loss, seizures, meningitis, neurological deficits, etc.).^{7,9} The algorithm for repair of tegmen defects remains open for debate,⁹ although four approaches comprise the cornerstones of treatment⁴: middle cranial fossa, transmastoid, a combination of these two, or middle ear obliteration. Here, we present the use of keyhole mini-craniotomies alone to successfully treat three patients.

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Clinical Presentation: Case Series

Clinical Presentations

The three cases were similar in their etiology, presentation, and imaging. All three were female patients, aged 57 to 69 years old, presenting with right-sided hearing loss and auricular fullness. They were evaluated by otologists, who noted frequency-dependent mild to severe hearing loss on the right side. They were diagnosed with chronic otitis media with effusions and thus underwent placement of tympanostomy tubes. After this, all three women had months of persistent CSF drainage from the right ear, reproducible on exam. Thin-cut computed tomography (CT) and magnetic resonance imaging (MRI) scans showed right-sided tegmen dehiscence (largest ~10 mm), encephaloceles along the middle cranial fossa, and mastoid effusions (representative images in ►Fig. 1, with two also having tegmen thinning or small defects on the left without encephaloceles). Patients consented to the publication of their image(s). Per institutional requirements, no institutional review board review was required for this operation. Patients provided informed consent to undergo this procedure with the attending neurosurgeon.

Operative Technique

In our first case, we placed a lumbar drain and did not use any hyperosmolar agents, whereas in the latter two cases, we did not place a drain, instead using mannitol and slight reduction

of end-tidal CO₂. Patients were positioned supine, in a Mayfield clamp, with the middle fossa floor perpendicular to the ground. Navigation based on MRI and CT was utilized to plan an approximately 3-cm curvilinear incision above the ear (►Fig. 2B), for a planned 3 × 2 cm craniotomy centered along the petrous ridge. During exposure, we harvested a 2 × 2 cm² temporalis fascia graft before visualizing temporal bone. After making one small burr hole with an acorn bit, we turned the mini-craniotomy with a B1 footplate (see ►Fig. 2A for craniotomy in vivo and ►Fig. 2C for 3D-postoperative CT reconstruction). A 3-mm diamond burr was used to drill down the lateral edge of the bone and expose the middle fossa floor. We performed extradural dissection without use of retractors, gently working along the petrous ridge under microscopic visualization posteriorly-to-anteriorly to protect the greater superficial petrosal nerve (GSPN). Facial nerve monitoring showed no changes.

In the first case, the dural defect with encephalocele was just medial to the arcuate eminence and superior semicircular canal, and in the latter two cases, the defects were lateral. CSF was seen copiously pouring out of the defects. The encephaloceles were resected and reduced. For intradural repair, a 2-cm dural opening was created along the lateral temporal dura and a subtemporal approach was then carried out to inspect the middle fossa floor dura. A collagen dural substitute (DuraGen, Integra LifeSciences Corp) inlay graft was placed to cover all dural defects, extending past the bony defects. Then, the temporalis fascia

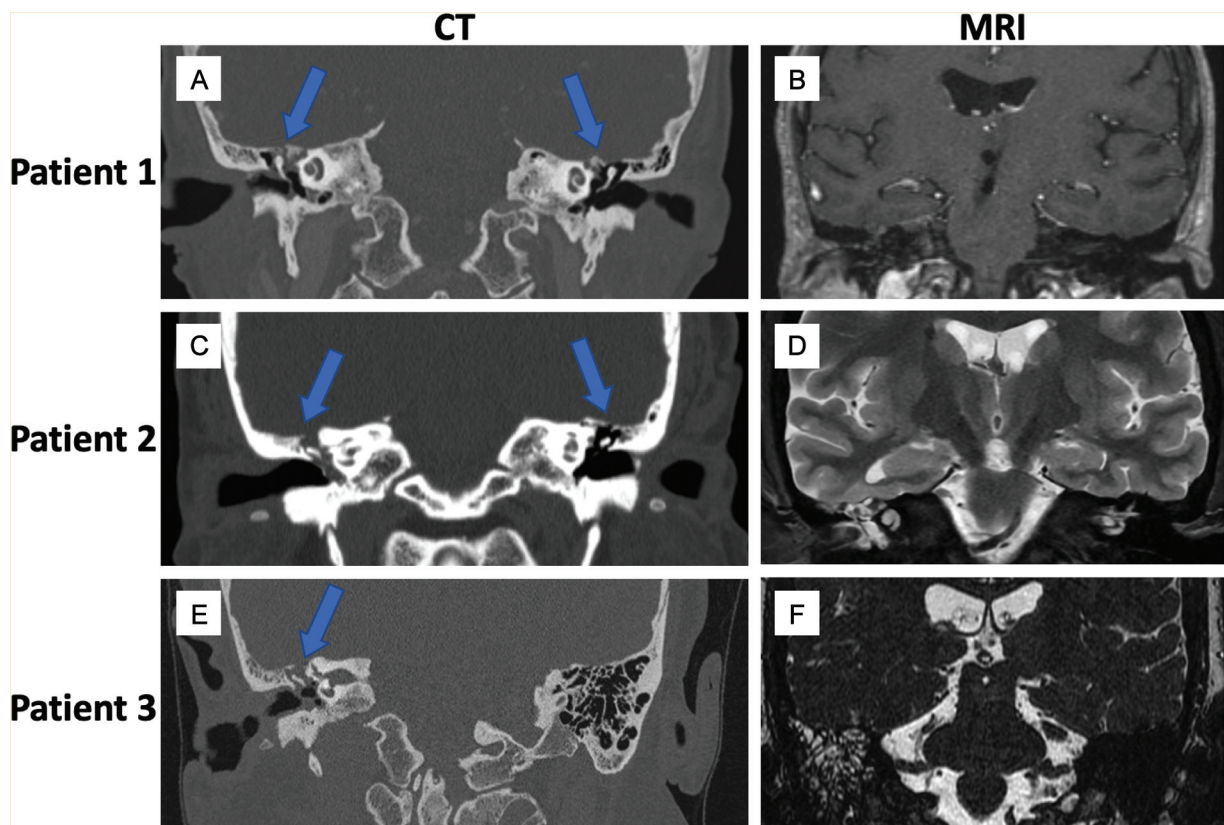


Fig. 1 (A, C, E) Preoperative coronal computed tomographies (CTs) demonstrating multiple tegmen defects bilaterally. (B, D, F) Preoperative magnetic resonance imaging (MRI) demonstrating suspected right-sided encephaloceles through tegmen defects.

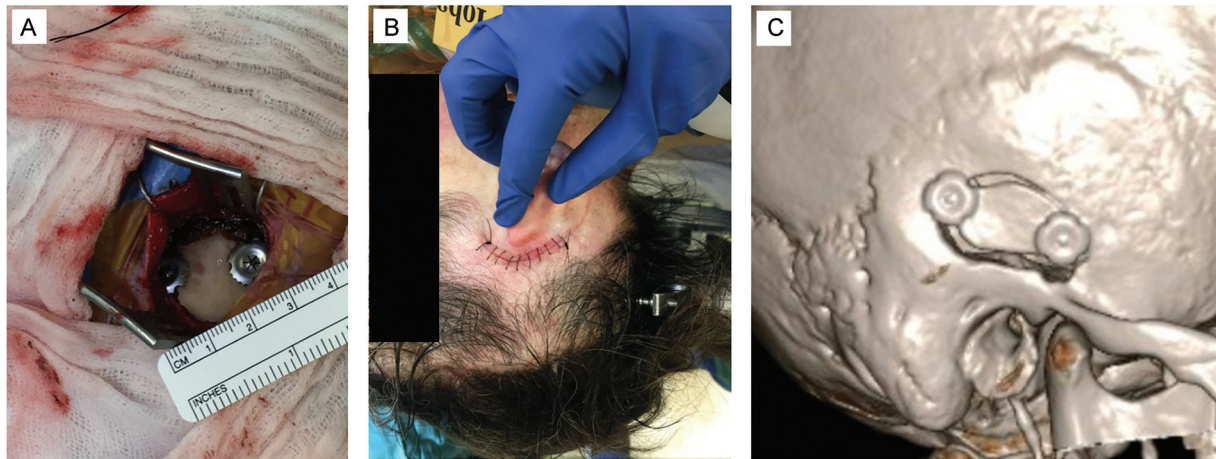


Fig. 2 Representative views of intraoperative craniotomy (A), incision at closure (B), and postoperative three-dimensional computed tomography scan showing the right-sided craniotomy (C).

graft was placed in an extradural onlay fashion, again extending past the bone defects. Watertight closure was achieved of the iatrogenic dural opening using 6–0 prolene suture. A third layer using another DuraGen onlay was then placed. The whole repair area was then coated with a fibrin tissue sealant, with care to avoid transit into the middle or inner ear structures conceptualized in ►Fig. 3. With microscopic view shown in ►Fig. 4. In one case with a larger bony defect, a split thickness bone graft from the cranioto-

my was also fashioned and placed over this reconstruction (conceptualized in ►Fig. 3). Closure was done in anatomical layers.

Postoperative Course

The first patient was maintained with 15 to 20 mL/h of CSF drainage for 24 hours, whereas the latter two were not. All patients were discharged on postoperative day 1 or 2. A 2-week levetiracetam taper and 4-day dexamethasone taper

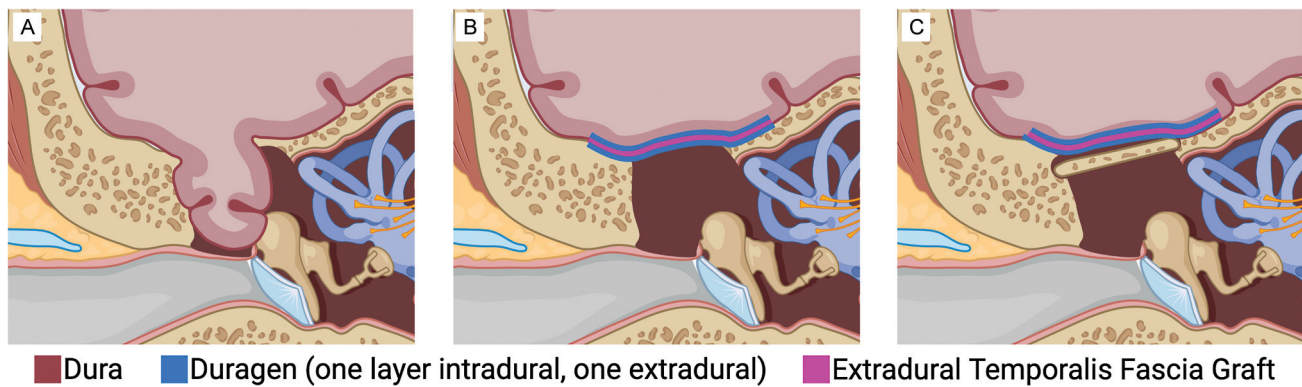


Fig. 3 Illustration of multilayered tegmen repair with both intradural (DuraGen inlay) and extradural (temporalis fascia graft, DuraGen onlay, fibrin sealant not pictured, and bone graft) components. (A) pre-repair, (B) multilayered tegmen repair, (C) multilayered tegmen repair with split-thickness bone graft placed. Created with BioRender.com.

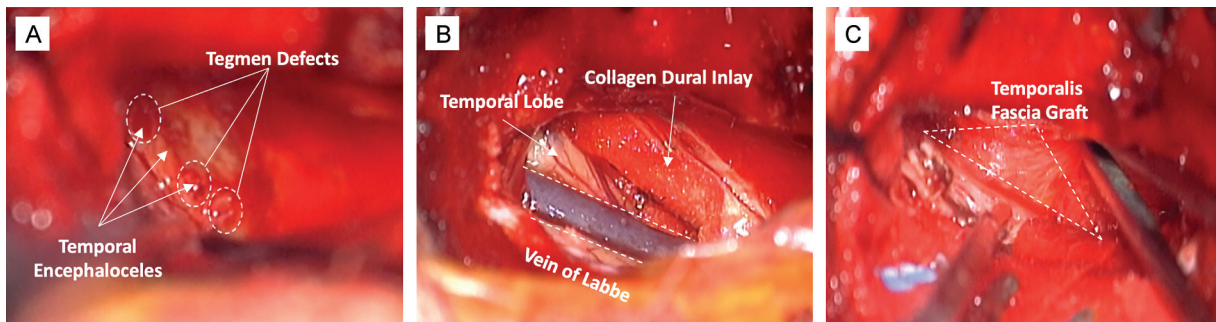


Fig. 4 (A) Three tegmen defects identified extradurally, prior to reduction of encephaloceles. (B) Visualization of vein of Labbe via keyhole craniotomy and dural inlay after completion of intradural portion, prior to watertight closure. (C) Fascial graft placed extradurally.

were prescribed. At 6 months postoperatively, all three patients remained free of otorrhea.

Discussion

The Keyhole Technique

We accomplish the goal of surgery with a 3×2 cm (6 cm^2) craniotomy. The traditional middle fossa craniotomy (MFC) is approximately 5×5 cm,¹⁰ and even in more modern case series, they are around 4×4 cm^{4,11} or 4.5×4.5 cm,^{12,13} leading to craniotomy surface areas of 16 to 25 cm^2 —approximately three to four times larger than ours. Additionally, it is common to use larger incisions, especially when combining with a transmastoid approach (e.g., $6 \text{ cm}^{10,11}$). Some groups use a longer pterional incision.^{12,13}

Neuronavigation allows for targeting the keyhole approach to pathology specific to a given patient. This is especially valuable when defects are small and numerous, as in some of our cases. Despite the small incision, a generous temporalis fascia graft may still be harvested while minimizing temporalis disruption. Ultimately, the keyhole craniotomy does not limit visualization of critical middle cranial fossa structures (petrous ridge, GSPN, arcuate, etc.). Equally important, the keyhole does not preclude a thorough intradural exploration and repair of defects. When indicated for larger defects (generally $>1 \text{ cm}^{14}$), it is also still possible to employ rigid reconstruction of the skull base through this small opening. Even with keyhole repairs, we learned that a lumbar drain is not usually necessary (as others have demonstrated,¹³ although practice patterns still vary), further reducing admission duration, discomfort, and cost.

The keyhole concept for this pathology is gaining popularity. Hernandez-Montero et al have employed MFCs of 3×2 cm, although they most commonly use a combined transmastoid approach and do not advocate for the MFC alone in their algorithm.¹⁵ Walia et al use a 4×2 cm craniotomy, although always part of a combined approach.¹⁰ In their review, Tolisano and Kutz recommend a craniotomy size of approximately 3×3 cm.¹⁶ Roehm et al use an expanded burr hole with an endoscopic approach and titanium reconstruction, although keep a lumbar drain in postoperatively, with discharge typically on postoperative day 4 to 5.¹⁷

Choosing a Surgical Approach: When Not to Use the Keyhole

The transmastoid approach is useful for posterior fossa bony defects, large encephaloceles extending into the mastoid, and small ($<1 \text{ cm}$) defects in frail patients who may not tolerate even minimal temporal lobe manipulation. It will still be limited to more posterior/lateral pathology and may put the ossicular chain at risk.¹⁷ Middle ear obliterations should be reserved for patients with already poor hearing and no alternative options.⁴ The locations of bony defects in the middle fossa should not preclude a keyhole

craniotomy; rather, they may determine its specific location.

Conclusion

We describe the use of a keyhole mini-craniotomy for tegmen defect repair, without need for mastoidectomy, days of lumbar drainage, or extended hospital stay. This gives excellent cosmesis, reduced tissue disruption, and minimal temporal lobe retraction in carefully selected patients.

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Conflict of Interest

None relevant to discussed techniques. Patrick Codd: Chief Medical Officer of Mente Inc., hold stock and ownership. Chief Scientific Officer of Thexa Technologies Inc., hold stock and ownership. Ownership and consulting revenue through Brainso LLC.

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