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Hydroxyapatite Cement Resurfacing the Dehiscent Jugular Bulb: Novel Treatment for Pulsatile Tinnitus

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Objectives/Hypothesis: The objectives were to discuss the presentation and symptomatology of patients with jugular bulb abnormalities, summarize the literature describing jugular bulb abnormalities, compare methods of treating symptomatic dehiscent jugular bulb, describe a novel surgical technique and pitfalls to repair dehiscent bulbs with hydroxyapatite cement, and present a case series to demonstrate outcomes with this technique.

Study Design: Case series presentation, PubMed literature review, and description of operative technique.

Methods: A series of patients presenting with pulsatile tinnitus due to dehiscent jugular bulbs who underwent operative repair with hydroxyapatite cement resurfacing is described. Literature review was conducted via a PubMed database search. Abstracts and references were reviewed to identify relevant sources. Surgical technique of repair and outcomes are reported.

Results: Three patients who presented with unilateral, bothersome, pulsatile tinnitus with history and imaging consistent with a diagnosis of high riding, dehiscent jugular bulbs underwent jugular bulb resurfacing with hydroxyapatite cement. Two patients associated the onset of their symptoms with trauma. All patients reported complete resolution of their tinnitus at an average follow-up of 15 months. No hearing, vestibular, or intracranial complications were encountered.

Conclusions: Compressive, obliterative, and endovascular interventions have been attempted to treat pulsatile tinnitus due to high-riding dehiscent jugular bulbs. Reconstruction of the middle ear floor with autologous tissue grafts has also been described. These techniques have been associated with variable results and with the risk of increased intracranial pressure. Hydroxyapatite cement resurfacing may be considered as an alternative for the treatment of this pathology.

Key Words: Pulsatile tinnitus, jugular bulb, high-riding jugular bulb, dehiscent jugular bulb, hydroxyapatite.

Level of Evidence: 4.

INTRODUCTION

The jugular bulb (JB) is a venous structure in the posterior cranial fossa created as the sigmoid sinus transitions to the internal jugular vein at the jugular foramen. It is usually located below the hypotympanum and is separated from middle ear structures by a bony encasement. Rarely, the JB can extend vertically above the inferior aspect of the annulus of the tympanic membrane and be found within the middle ear, an anatomic abnormality known as a high-riding jugular bulb (HJB), or the bony encasement can be incomplete, known as a dehiscent high jugular bulb (DHJB). In early cadaveric temporal bone studies, an HJB was found to have a prevalence of 6%.1 In 2012, Friedmann et al. studied cadaveric temporal bones and correlated clinical findings with computed tomography (CT) images.2 In this study, histology from 1,579 temporal bones were examined, and 100 CT scans of the temporal bones were reviewed. High JBs were noted histologically in 8.5%, with an 8.2% incidence radiographically. Erosion into inner ear structures was present in 2.8% on histology and in 1.5% radiographically. The prevalence of JB abnormalities increased with age, reaching 10% to 11% in the 41- to 60-year-old age range, with no difference in laterality or gender.2 A larger series reviewing CT scans from 350 patients (700 temporal bones) found a higher incidence of both HJB and DHJB on the right (26.9% and 5.7%, respectively) compared to the left (13.7% and 2.0%, respectively).3Patients with these abnormalities have a variety of presentations, from being asymptomatic to reporting hearing loss, pulsatile tinnitus (PT), and vertigo.4

There are no known medical treatments for PT due to DHJB, though both obliterative surgical and endovascular stenting treatments have been described.4,5 However, variable efficacy in controlling PT coupled with potentially serious complications have prompted a search for alternative management strategies for this patient population. One such strategy involves reinforcing, or “soundproofing,” the DHJB. In 2010, El-Begermy and Rabie described a multilayer reconstruction of the middle ear floor using a variety of autologous tissue grafts.4 Although relatively effective and simple, PT disappeared in only 57% of patients in this series. Additionally, this technique has the potential risks of donor-site morbidity...
associated with endaural incisions, canalplasty (for bone dust harvest), and tragal cartilage with perichondrium grafting.

One alternative to the use of autologous tissues is hydroxylapatite (HA) cement, a product familiar to most otologists. In this series we describe a novel technique for the treatment of PT associated with DHJB by reinforcing the bony separation between the JB and middle and inner ear structures.

**MATERIALS AND METHODS**

**Surgical Technique**

Preoperatively, the risks and benefits of operative intervention are discussed with patients, including the failure of symptoms to improve. General anesthesia is induced and patients are intubated, prepped, and positioned for a transcanal approach. A posterior–inferior-based tympanomeatal flap is raised. The length of the flap should be longer than what is typically utilized in case removal of the inferior medial bony tympanic annulus is necessary to adequately visualize the JB and round window niche. Caution should be exercised during flap elevation because the JB is likely higher and dehiscent, so more vulnerable to injury during this stage. The middle ear cavity is examined for soft tissue such as adhesions or JB diverticula, which should be addressed. The JB is gently palpated to identify sites of dehiscence or exposure. The round window niche is protected with a small piece of saline soaked Gelfoam before mixing and applying HA over the contour of the JB. Less than 1 cm² of cement is needed. The HA is allowed to set before removing this Gelfoam to prevent occluding the round window, which would likely cause hearing loss. No middle ear packing is used. The tympanomeatal flap is then laid back. Postoperative care consists of avoiding straining for 2 weeks after surgery.

**Case Series**

**Case 1.** A healthy 50-year-old female presented with sudden onset of severe right-sided pulsatile tinnitus. She described it as very loud swishing and whooshing that would bother her throughout the day, but was worse in quiet situations especially when lying down. Her body mass index (BMI) was 37.4. Otoscopic examination was normal, and skull and neck auscultation revealed no bruits. Compression of the neck on the right did curtail the noise, although she could still hear it if she concentrated. Her audiogram was normal. High resolution computed tomography (HRCT) and computed tomography angiography (CTA) confirmed the presence of an ipsilateral DHJB. She underwent uncomplicated transcanal resurfacing of the JB with HA cement under general anesthesia and tolerated the procedure well. A tymanomeatal flap was raised, and immediately resting against the round window was the JB. The bulb was not appreciated with microscopic examination of the tympanic membrane in the office or the operating room. The bulb was palpated and found to be dehiscent. It was gently compressed with saline soaked Gelfoam, and then the application of HydroSet (Stryker, Kalamazoo, MI) took place to reconstitute a bony barrier between the JB and the middle ear cleft. At her 1-week postoperative visit, she noted complete resolution of the PT. The 3-month postoperative examination revealed a well aerated middle ear with an intact and normal appearing tympanic membrane. Her audiogram remained unchanged. Telephone interview at 5 years postoperatively confirmed absence of any PT.

**Case 2.** A healthy 70-year-old male presented with a 4-year history of severe right-sided pulsatile tinnitus. It began suddenly after forcefully popping his ears open during an upper respiratory infection. He described it as a constant, very loud, pulse-synchronous whooshing that had not changed in intensity since onset. By turning his head to the left he was able to decrease the intensity of the pulsations. His BMI was 30.5. Otoscopic examination was normal, and skull and neck auscultation revealed no bruits. An audiogram demonstrated bilateral, normal, low-frequency hearing sloping to asymmetric, right greater than left, severe high-frequency sensorineural hearing loss. Magnetic resonance imaging was negative for retrocochlear pathology. Magnetic resonance venography demonstrated a large right JB closely associated with the middle ear with a possible filling defect. HRCT of the temporal bone revealed a DHJB. He underwent transcanal middle ear exploration via a posteroinferiorly based tympanomeatal flap. Intraoperatively, a thin layer of cracked, eggshell-like bone was noted over the JB, so that the bulb could be gently compressed. Also noted was a small adhesion band from the JB to the round window membrane. The JB was resurfaced with Otomimix (Olympus America, Center Valley, PA) HA cement, and the patient tolerated the procedure well. He noted immediate resolution of the PT in the recovery room. He remained asymptomatic through his 3-month postoperative examination when he was noted to have a well aerated middle ear with an intact and normal-appearing tympanic membrane. His postoperative audiogram was stable.

![Fig. 1. Noncontrasted computed tomography temporal bone through the jugular bulb demonstrating dehiscence into the middle ear (axial plane).](image1)

![Fig. 2. Noncontrasted computed tomography temporal bone through the jugular bulb demonstrating dehiscence into the middle ear (coronal plane).](image2)
with no change in his pure-tone average or speech discrimination. HRCT of the temporal bone showed a well-covered JB within the middle ear. He remains asymptomatic 17 months postoperatively.

**Case 3.** A healthy 64-year-old female presented with a 2-year history of worsening right-sided pulsatile tinnitus. It began shortly after frontal and parietal subdural hematomas were sustained when she fell down 10 stairs with associated loss of consciousness. During her convalescence she noted mild whooshing in her right ear only, which became louder over the course of the following year. She described it as constant, very loud pulse-synchronous noise that worsened if she laid on her right side. Her BMI was 32.5. Otoscopic examination was normal, and skull and neck auscultation revealed no bruits. An audiogram was normal. A CTA ordered by an outside otolaryngologist was suggestive of a right DHJB, which was confirmed by HRCT of the temporal bone (Figs. 1 and 2). She was noted to have thin, but intact bone overlying both superior semicircular canals. She underwent transcanal middle ear exploration via a posteroinferiorly based tympanomeatal flap. Intraoperatively, a very thin layer of bone was noted over the JB, so that the bulb could not be compressed (Fig. 3). Also noted was a small adhesion band from the JB to the round window membrane. The JB was resurfaced with Otomimix HA cement, and the patient tolerated the procedure well (Fig. 4). At her 1-week postoperative visit, she noted near complete resolution of her PT. She remained asymptomatic through her 3-month postoperative examination, when she was noted to have a well-aerated middle ear with an intact and normal appearing tympanic membrane. Her audiogram had an asymptomatic decrease in pure-tone averages of 5 dB. HRCT of the temporal bone showed a well-covered JB within the middle ear (Figs. 5 and 6). She remains asymptomatic 4 months postoperatively.

**DISCUSSION**

Pulsatile tinnitus merits a thorough history and investigation due to its broad differential. The etiology of pulsatile tinnitus is most commonly due to intracranial venous abnormalities, such as sigmoid sinus diverticulum, HJB, DHJB, or transverse sinus stenosis. Arterial etiologies are less common, and frequently due to cervical carotid atherosclerotic disease or other carotid abnormalities. In some of the population, no definite diagnosis can be determined. Rarer nonvascular causes have also been described, such as conductive hearing loss, semicircular canal dehiscence, glomus tumor neoplasms, and benign intracranial hypertension. Careful history and physical exam can guide clinicians toward a diagnosis, and thoughtful imaging can be used for confirmation.
If presentation and imaging are suggestive of a JB abnormality, multiple treatment options are available. Jugular vein ligation, compression, and obliterator techniques are effective but have been associated with the risk of increasing intracranial pressure. To avoid this, confirmation of a functioning contralateral drainage system is often recommended preoperatively. Endovascular embolization of an HJB is also feasible, yet maintains the risk of increased intracranial pressure. If a stent is used to attempt to maintain JB patency, patients must be placed on anticoagulation, and this can be associated with risk of ischemic stroke and delayed thrombosis.

Reconstruction of the middle ear floor with a soundproof construct of layers of autologous tissue grafts has been reported in a small series of patients. The JB encasement was rebuilt using a tragal cartilage graft with attached perichondrium and bone dust. Of seven patients included in this series, five (71%) had improvement of their pulsatile tinnitus and two (28%) patients reported a change in the quality of the tinnitus but did not have symptomatic improvement. One procedure was performed transcanal and the other six utilized a postauricular approach. One patient developed blurry vision, papilledema, and binaural visual field defects concerning for optic nerve compression, thought to be due to sigmoid sinus obstruction and stenosis on the operated side leading to increased intracranial pressure. She eventually improved with acetazolamide and therapeutic warfarin treatment for 6 months.

The described transcanal JB resurfacing technique using HA is proposed as an option for the treatment of pulsatile tinnitus due to high or dehiscent JB. There are several advantages to this method of repair. The transcanal approach avoids a retroauricular incision and avoids a second incision for a tragal cartilage graft. If greater exposure is desired, a postauricular hypotympanic approach remains an option. HA is commonly used in otologic surgery and is familiar to surgeons. It sets quickly within minutes and does not shift over time, so there is low risk of inadvertent graft migration, which may contribute to JB stenosis or occlusion. Although there were no complications in this series, it is limited in its retrospective, case series design, and by the small number of patients included. Short-term surgical outcomes are promising; however, long-term follow-up has yet to be obtained. Delayed complications, such as a theoretical risk of graft infection, are possible. HA does represent a nonvascularized foreign body in the middle ear space, which could hypothetically get infected and necessitate its removal.

It is important to have a high suspicion that the JB abnormality present is the only cause of a patient’s symptoms. Venous pulsatile tinnitus is an acquired condition arising with two required elements; first, turbulent flow must be present, and second, there must be a route for the sound to enter the middle ear. Turbulent flow can be caused by abnormalities anywhere in the sigmoid-jugular system, so careful evaluation of both the sigmoid sinus and JB on imaging is worthwhile. In our experience, PT originating from the sigmoid sinus only occurs in cases where there is an anatomic abnormality (diverticula, sigmoid sinus wall dehiscence, or very large caliber sinus), which would be evident on a preoperative CT scan. This case series describes three healthy adult patients, all with similar age and BMI, with right-sided pulsatile tinnitus. The ipsilateral sigmoid sinus appeared normal in each case. Two patients had a history suspicious for a post-traumatic etiology of their pulsatile tinnitus. The JB abnormalities presented represent a range of severity, from obvious dehiscence to hairline fracture to intact but thin bone. Although the series is small, all patients had resolution of their pulsatile tinnitus with preservation of hearing, and no complications were encountered.

Although conceivably performed under local anesthesia, the authors believe that the risks of potential JB injury (however unlikely) necessitate the establishment of a more stable airway. High JB injury was first described by Page in 1914 when he encountered massive bleeding after myringotomy in a 10-month-old infant, which was controlled with packing of the ear canal, but resulted in sigmoid sinus thrombosis and the patient’s death. It has continued to be a risk reported with otologic surgery, including myringotomy and during tympanomeatal flap elevation.

As with all otologic surgery, delicate technique is paramount to optimal outcomes. To properly visualize the JB, an inferior or posteroinferiorly based tympanomeatal flap should be utilized. The length of the flap should be longer than what is typically utilized, as removal of the inferior medial bony tympanic annulus may be necessary to afford adequate visualization of both the JB and the round window niche. Palpation of the JB can confirm the presence of an intact boney covering. However, this series suggests that the presence or thickness of bone overlying the JB may have no significant bearing on the success of resurfacing. The reason for this is more likely due to soundproofing of the middle ear from the altered flow dynamics within the JB, rather than by directly addressing underlying intraluminal pathology.

Two cases were noted to have adhesions from the JB to the round window niche. Although theoretically, pulsations from the JB transmitted to the round window membrane may account the subjective tinnitus, this is more likely an incidental finding. Mucosal adhesions within the middle ear are commonplace, and certainly would not account for the pulsatile tinnitus in the patient without adhesions noted. Along these lines, it is critical to avoid cement settling into the round window niche, as doing so would likely results in hearing loss. Moreover, subsequent removal of cement plugged within the round window niche would also place the patient at unnecessary risk for hearing loss. To avoid this, the authors recommend placing a small piece of saline soaked Gelfoam into the niche, and not removing it until the cement has sufficiently hardened.

CONCLUSION
Transcanal JB resurfacing with HA is an option for the surgical treatment of pulsatile tinnitus due to high riding or dehiscent JBs. It avoids the risk of endovascular intervention and the donor morbidity of a layered tragal cartilage graft. Although this series is limited in
its retrospective, case series design, and by the small number of patients included, no significant complications of hearing loss, sinus thrombosis, or recurrent symptoms were encountered. Appropriate workup and counseling could allow for this novel technique to help patients with pulsatile tinnitus who otherwise had limited or no options.

**BIBLIOGRAPHY**