Percutaneous Balloon Compression for Trigeminal Neuralgia

Imaging and Technical Aspects

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Abstract: Trigeminal neuralgia attacks are among the most painful conditions known. Trigeminal neuralgias are hypothesized to be caused by neurovascular conflict at the trigeminal root entry zone in the preoptic cistern. A range of therapeutic options is available including open surgical microvascular decompression and several percutaneous ablative techniques (e.g., radiofrequency rhizotomy and glycerol gangliolysis). Percutaneous balloon compression of the Gasserian retroganglionic rootlets has been reported to have results comparable to those of other minimally invasive techniques. This operative approach has proven popular with neurosurgeons as it is considered to be technically easier to perform than other methods. Nevertheless, pain physicians might regard this technique as challenging, relatively risky, and requiring special expertise. Accordingly, in this imaging article, we describe our percutaneous balloon compression procedure, paying particular attention to the technical and radiological details.

METHODS

This paper provides an overview of the technical details of the PBC procedure and the possible errors that may arise during its performance. A brief overview of disease characteristics and minimally invasive procedures was described after literature review. Specifically, we then focused on the regional anatomy and its corresponding fluoroscopic visualization, to provide precise guidance for pain interventionists in their daily clinical practice.

DISCUSSION

Clinical Features Of TN

Idiopathic TN is characterized by attacks of recurrent paroxysmal pain in an area of the face innervated by the fifth cranial nerve. The pain is commonly evoked by ordinary trivial stimuli, and it is abrupt in onset and termination. The intensity is so severe that many patients never forget their first attack and recall it in great detail years later. Prominent features to be considered are shown in Table 1.

Although rare, TN is the most frequent diagnosis proposed for unilateral episodic facial pain. However, there is a paucity of population-based and clinical epidemiological research on TN. The recent reported incidence in general practices databases is 27 per 100,000 person years. It would seem that the annual occurrence rate in the Chinese population is even higher, at approximately 0.2%. International guidelines and the Cochrane reviews suggest that carbamazepine remains the primary drug of choice for TN. Nevertheless, about half of all patients eventually require surgery for pain relief, because of drug resistance or drug intolerance.

Minimally Invasive Options

If medical treatment is deemed unsuitable, there are 4 appropriate ablative possibilities. These possibilities are as follows:

1. γ Knife. The γ knife entails high dose irradiation of a small section of the trigeminal nerve. The use of radiosurgery is still under scrutiny, and further studies are required to clarify its role in the treatment of TN.

2. Glycerol gangliolysis. Stereotactic injection of glycerol into the cistern of the Meckel cave has the potential to abolish pain in patients with TN. To this end, it is essential to optimally place the needle, and bring the patient into a sitting position before injecting the chemoneurolytic agent. On these grounds, the results of glycerol gangliolysis are rather variable and this technique has caused more controversy than any other procedure.

3. RF-RT. RF-RT involves localized destruction of the specific retroganglionic rootlets coming from the region of the lancinating pain (somatotopic nerve mapping) and selectively destroying them by RF thermocoagulation. A specific degree and distribution

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The authors declare no conflict of interest.

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ISSN: 1098-7339

DOI: 10.1097/AAP.0000000000000292
of sensory loss is exchanged for relief of facial pain. The efficacy of RF-RT has been confirmed by many authors in large series of patients. The benefits of compression of the Gasserian ganglion (GG) were noted by Shelden and associates in the 1960s. They performed subtemporal craniotomies in an effort to decompress the trigeminal ganglion, but instead noted that compression and mechanical injury to the nerve with resultant sensory deficits produced better results. This same concept led Mullan and Lichtor to develop a percutaneous technique for compressing the GG using an embolectomy catheter. The PBC is distinct from the other 2 percutaneous techniques because it is carried out on a completely anesthetized, intubated patient. Compression of the trigeminal ganglion is thought to selectively injure the large myelinated fibers but does not seem to affect the smaller unmyelinated and nociceptive fibers, which are responsible for mediating the corneal reflex. Thus, treatment of first-division pain is reported to be safer because the possibility of disrupting this reflex is reduced. Grouping together the series of 100 patients or more published in the past 20 years, PBC treatment has been reported in more than 2000 cases, and complete relief pain was calculated to be 80% in 3 to 6 years.

Anatomy Of The Trigeminal Nerve

The trigeminal nerve is a mixed somatic nerve which carries sensation from the entire face and the anterior two thirds of the head. It extends from the side of the pons to the apex of the petrous portion of the temporal bone, where it expands into the GG located in MC. Meckel cave is a cleft-like dural pocket extending from the posterior fossa into the posteromedial portion of the middle cranial fossa; its mouth (the porus trigeminus) forms a natural connection between the 2 fossae. Meckel cave contains the roots of the trigeminal nerve, the GG with its 3 branches, and the arachnoid layer (Fig. 1). The dural-arachnoid pouch behind the GG constitutes the trigeminal cistern. This compartment contains cerebrospinal fluid and communicates with the prepontine cistern through the porus. The position of the trigeminal cistern in the lateral radiograph, after its opacification, is relatively constant; it lies just below the floor of the sella turcica and immediately anterior to the clivus.

Facilities Required For PBC

Radiologic Equipment

High-quality intraoperative imaging is mandatory. The preferred equipment is a C-arm fluoroscope that allows the x-ray beam to be directed at any angle. The x-ray tube should pass under the table and the intensifier above it; under-table x-ray tube systems subject the operator to much less radiation than scattered over-table systems.
To mitigate

A radiograph is taken for the record, and, after the ballon is inserted anteriorly and medially passing through inferior orbital fissure to the orbital apex

Positioning

Once anesthetized, the patient is placed in supine decubitus position with the head on a radiolucent headrest, maintained in a midline neutral position, and slightly extended.

The Anterior Transforaminal Route

The transjugal-transoval approach described by Härtel is the regular technique used to reach the ganglion percutaneously. The operator starts from a standard entry point, 3 cm from the oral commissure, and guides the needle toward the intersection of 2 planes, one sagittal through the center of the pupil and another coronal, 2.5 cm anterior to the tragus. The whole process is monitored with lateral fluoroscopic control.

Surgical Material

Conventional PBC instruments consist of a large trocar comprising a cannula and 1.5 mm longer internal needle, a no. 4 Fogarty catheter, a stopcock, a tuberculin syringe, and some non-ionic contrast medium. We use a kit approved for this procedure (Mullan Microcompression Set; William Cook Europe ApS, Bjæverskov, Denmark) which includes an introducing 14G cannula, sharp and blunt obturators, guiding stylets, and a no. 4 special balloon catheter. The end of the 14G cannula is smooth and both obturators are flush with it. This catheter offers some advantages over traditional embolectomy catheters; it adapts better to adjacent neural structures and has a smaller intraluminal dead space.

Operative Technique

Preparation

General anesthesia with endotracheal intubation and muscle relaxation is often used to make it a totally pain-free experience for the patient. In any event, because patient cooperation is not needed for functional localization, the whole procedure can be performed under short-lasting anesthesia without endotracheal tube. Alarming rises in blood pressure may occur during penetration of the foramen ovale (FO), and cannulation and mechanical distension of MC (Table 2). Equally common is a trigeminal cardiodepressive reflex with marked, but short-lived, bradycardia induced at the moment of inflation of the balloon. To mitigate these responses, we always administer atropine with an incremental target infusion of remifentanil before FO penetration.

TABLE 2. Adverse Effects and Complications of PBC

<table>
<thead>
<tr>
<th>Complications</th>
<th>Anatomical Cause</th>
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<tr>
<td>C-V stress</td>
<td>Reflex hypertension and trigeminal cardiodepressive reflex</td>
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<tr>
<td>Facial hematoma/A-V fistula</td>
<td>Puncture of internal MA and pterygoid plexus</td>
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<tr>
<td>Injury to ICA, jugular vein</td>
<td>Excessively medial displacement of the needle causing injury to the ICA in the FL, posterolateral displacement causing injury to the jugular vein</td>
</tr>
<tr>
<td>Injury to Eustachian tube</td>
<td>Posterior displacement of the needle</td>
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<tr>
<td>Blindness</td>
<td>Needle inserted anteriorly and medially passing through inferior orbital fissure to the orbital apex</td>
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<tr>
<td>Intracranial complications</td>
<td></td>
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<td>Carotid-cavernous fistula</td>
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<td>Temporal lobe hematoma</td>
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<td>Brainstem lesion</td>
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<td>Diplopia</td>
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<td>Meningitis</td>
<td>Oral mucosa puncture, contamination or improper sterility</td>
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</table>

A-V indicates arteriovenous; CN, cranial nerve; CS, cavernous sinus; C-V indicates cardiovascular; FL, foramen lacerum; ICA, internal carotid artery; MA, maxillary artery.

Locating the FO

The Härtel approach may not be suitable for all of the region’s numerous anatomical variations: there is a risk that the needle will be diverted from the correct route, leading to serious extracranial complications (Table 2). This hindrance can be avoided by clear visualization of the foramen and by navigating the needle in coaxial view, parallel to the direction of the x-rays, so that the hub is projected on the screen like a dot. The best way to locate the FO is via a modified submental view. To avoid erratic movements of the C-arm in search of the FO, we find it best to follow a stepwise protocol so that we know where we are at all times. We begin by visualizing the petrous ridges through the orbits in a posteroanterior (PA) projection, parallel to the orbitomeatal (OM) plane (Fig. 2A). From this position, we rotate the C-arm 20 to 45 degrees in the sagittal plane and follow the

For further reading, see:

1. Bjaeverskov, Denmark
2. Fogarty catheter
3. Bjaeverskov, Denmark
4. Stensen duct puncture
5. Puncture of internal MA and pterygoid plexus
6. Excessively medial displacement of the needle causing injury to the ICA in the FL, posterolateral displacement causing injury to the jugular vein
7. Needle inserted anteriorly and medially passing through inferior orbital fissure to the orbital apex
8. ICA injury in the CS
9. Dura mater penetration and intradural balloon inflation
10. Guiding style/balloon catheter far from the petrous ridge
11. Compression of CN VI (most common) or CN IV
12. Oral mucosa puncture, contamination or improper sterility

For additional information, please refer to:

1. Conventional PBC instruments consist of a large trocar comprising a cannula and 1.5 mm longer internal needle, a no. 4 Fogarty catheter, a stopcock, a tuberculin syringe, and some non-ionic contrast medium.
2. We use a kit approved for this procedure (Mullan Microcompression Set; William Cook Europe ApS, Bjæverskov, Denmark).
3. The PBC consists of 3 sequential stages, each with specific steps: (1) FO insertion, (2) MC cannulation, and (3) compression of the retroganglionic rootlets.
4. With a surgeon’s gloved finger in the mouth to ensure the oral cavity is not entered, the trocar ensemble is advanced until it penetrates the FO and its tip is set over the clival plane. Then the inner needle is removed, and a 4F Fogarty catheter with its fine wire assembled is introduced until 1 cm of catheter lies beyond the cannula tip. After stylet withdrawal, the balloon is inflated with contrast material to an arbitrary degree and held in that position for an arbitrary time. The balloon should be distended until it begins to protrude toward the posterior fossa and a squeeze is being achieved.
5. A radiograph is taken for the record, and, after the balloon is deflated, the catheter and cannula are removed together. Finally, the cheek is compressed against the maxilla for a few minutes to minimize the development of a hematoma.

For more details, please consult:

1. General anesthesia with endotracheal intubation and muscle relaxation is often used to make it a totally pain-free experience for the patient.
2. In any event, because patient cooperation is not needed for functional localization, the whole procedure can be performed under short-lasting anesthesia without endotracheal tube.
3. Alarming rises in blood pressure may occur during penetration of the foramen ovale (FO), and cannulation and mechanical distension of MC (Table 2).
4. Equally common is a trigeminal cardiodepressive reflex with marked, but short-lived, bradycardia induced at the moment of inflation of the balloon.
5. To mitigate these responses, we always administer atropine with an incremental target infusion of remifentanil before FO penetration.

For further discussion, see:

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caudal displacement of the rim of the petrous ridge until it is at the level of the maxillary sinus (Fig. 2B). Then all that remains is to rotate it obliquely in the axial plane 10 to 25 degrees toward the affected side until the petrous apex is situated below the maxillary sinus and above the jaw. The whole process is relatively easy to trace by observing the simultaneous movement of the mastoid air cells of the temporal bone. We then slowly rotate the C-arm once again in the sagittal plane, back and forth, until we identify the FO (Fig. 2C).

**Determination of the angle**

After conclusive identification of the foramen, one must decide how to address it at the correct angle. The GG and its plexus triangularis is a highly flattened structure resting close on the anterior surface of the petrous bone. Therefore, for a needle to penetrate the ganglion longitudinally, it must follow a path parallel to this surface and must not deviate from this direction. Unfortunately, the inclination of the anterior surface of the petrous bone with respect to the OM plane is extremely variable. However, postmortem examinations have shown that to enter the thin ganglion, and the sensory root behind it, the angle of the needle should be kept low by entering the skin of the cheek as high as possible and passing obliquely through the foramen (Fig. 3).

**FO shape and position**

The contour of the FO varies with the angle of incidence of the central ray with respect to the plane of the orifice. A caudal tilt of our tube will transform the foramen into an almost circular shape. A more tangential direction, that is, with the C-arm vertical, will make the foramen flat, like a slit. Naturally, this latter projection takes the entry point higher up on the cheek, precisely the right angle that will be oriented toward the trigeminal root (Fig. 3).

It should be borne in mind that the lateral third of the FO is a direct route of access to the media fossa and therefore to the temporal lobe. Thus, it is advisable to increase the degree of C-arm obliqueness so that the FO is positioned contiguous to the projection of the coronoid process; the FO should be penetrated close to the midportion of the foramen.

**En route**

Once the appropriate radiological passage has been determined, by means of a spinal needle we inject 10 mL of 0.5%...
lidocaine without epinephrine into the cheek along the intended path of the cannula. This injection minimizes the chance of intraoral penetration of the 14-gauge cannula by creating a submucous “pass” between the lateral pterygoid plate and the condyle of the mandible. Then, we move the cannula in tunnel vision toward the anterior edge of the FO up to the infratemporal fossa.

**Checking in the lateral and PA projection**

A true lateral view is achieved by superimposing the auditory meati and the orbital roofs (Fig. 4A). The ideal positioning of the cannula tip will be approximately 5 mm anterior to the temporomandibular joint and aimed at the intersection of the shadows of the clivus and the petrous ridge (Fig. 4B). The image intensifier is then oriented in the PA direction shooting down the OM line so that the petrous ridge is visualized through the orbit. The target site in this dimension is a point approximately 9 mm medial to the lateral rim of the internal auditory meati. This usually coincides with the medial extent of a dip that occurs in the petrous ridge (Fig. 5). This notch corresponds to the proximal entrance to MC, the porus.

**Engaging the FO**

We subsequently slide the tip of the cannula backward until it is about to penetrate the 2 edges of the FO; the posteroinferior margin of the foramen acts as a wedge, preventing further slippage of the cannula. From that point, we redirect it in the cranial direction, along the cleavage plane of the anterior surface of the petrous...
ridge. There is some resistance to the cannula while it slips into the FO; the cannula should not penetrate any further (Fig. 4B).

Potential pitfalls
Venous bleeding emerging from a properly placed cannula may arise from a venous sinus crossing the FO and does not complicate the course of the operation. However, arterial pulsating bleeding may originate from the carotid artery or an accessory meningeal artery traversing the FO.

In either case, the procedure is best terminated and deferred for a few weeks.

MC Cannulation

Threading the catheter and inflating the balloon
We direct the catheter to the center of the porus, just at the upper rim of the petrous ridge or slightly below (Fig. 6A). Mild resistance is usually encountered before entry into the cave. We check again in the lateral projection, and confirm that the tip of the catheter is situated at the junction of the clivus and the petrous ridge. The balloon is then slowly inflated with contrast agent. As the balloon is filled it takes on a spherical shape which, as inflation continues, ends up adopting its peculiar piriform appearance. We pursue a fully developed pear-shape balloon with a small nipple protruding into the posterior fossa (Fig. 4D), and keep it inflated for 1 minute.

Cave cannulation
In 15% of our cases, MC cannulation is initially unsuccessful as indicated by the inappropriate shape and position of the balloon, and the catheter must be repositioned until the characteristic shape appears. In most instances, MC cannulation is accomplished after modifying the slope of the needle with respect to FO.

Balloon misplacement
Suboptimal balloon positions, inflated outside MC, can inadvertently damage adjacent brain structures (Table 2). Especially, one must be wary of cylindrical-shaped, or “in vitro” like, balloons as they represent an erroneous extracisternal location of the

FIGURE 5. A disarticulated right temporal bone (A-B) is radiographed in straight PA view, like the patient in (C), to visualize the internal auditory canal through the petrous pyramid. In (B), a small screw has been inserted in the internal auditory meatus and a small lead ball fixed in the trigeminal porus to show the correspondence between the 2 targets. White arrowheads indicates posterior wall of the porus acousticus; black arrowhead, porus trigemini.

FIGURE 6. Percutaneous balloon compression. A, The balloon has been threaded until just below the upper rim of the petrous ridge; observe the thin inner wire that identifies its position (black arrowhead). B, The balloon has been inflated with 0.7 mL of iohexol within the porus and is compressing the retrogasserian fibers against the firm petrous ridge and the tentorial attachment.
catheter. This can be verified and adjusted accordingly with the use of a frontal fluoroscopic projection\textsuperscript{22} (Fig. 6B). On other occasions (20%), the balloon migrates partly or totally into the posterior fossa before adequate pressure could be reached in MC (Fig. 4C). In these “hourglass” shapes, we recommend inflating the balloon to maximum capacity and slightly withdrawing the catheter until it assumes its customary pear shape\textsuperscript{23} (Fig. 4D); we maintain traction to prevent it from herniating into the cerebellopontine cistern, and perform frequent fluoroscopic controls of its position in relation to the floor of the sella.

**Compression Of The Retroganglionic Rootlets**

**Balloon volume**

The balloon volume necessary to achieve adequate ganglion compression ranges from 0.6 to 1.2 mL, with a mean value of 0.75 mL.\textsuperscript{23} As MC size is variable, there is no correlation between the filling volume and the pressure attained inside the cave. Hence, it is not the injected volume but the radiological shape the main criterion that an effective compression is being applied.

**Compression time**

Once an appropriate pear-shape is reached, 60 seconds suffices to elicit a good functional outcome, which limits the duration of compression-related C-V instability.

**Adverse Effects And Complications**

**Dysesthesia**

After PBC, ipsilateral hemifacial hypoesthesia is a more or less unavoidable adverse effect associated with a successful operation.\textsuperscript{16} In many cases, perception for touch and pinprick is almost normalized within 1 year.\textsuperscript{23} As we usually inflict vigorous ganglion compression, a quarter of our patients complain of abnormal sensations over time such as tingling, pulling, itching, or stiffness in one or more trigeminal divisions. However, except for a small percentage of cases (<5%) who reported dysesthesia as seriously annoying, the majority describe those sensations as mild.

**Diplopia**

Due to its anatomical location at the lateral wall of the cavernous sinus, the most frequently damaged cranial nerve during PBC is the abducens nerve\textsuperscript{25} (Table 2). Hence, inflation of the balloon should be abandoned when intraoperative imaging shows a higher than expected extension, toward the sellar floor. Double vision is transitory and shows total or close to total regression in weeks or months, notwithstanding.\textsuperscript{16}

**ACKNOWLEDGMENTS**

The author thanks his brother Jaime de Córdoba, full Professor at the University of Fine Arts in Barcelona, for the superb illustrations of the trigeminal nerve and the human skull; Dr Patrick Mullen, anesthesiologist at Countess of Chester Hospital, for the invaluable comments on the text; Mr Juanma Luna, Radiology Technician at the Hospital of Mollet, for the work in obtaining radiological material for the writing of this paper; and Dr Rosario Sarabia, Chief of Neurosurgery at the Rio Ortega University Hospital in Valladolid, for supplying him with her doctoral thesis on PBC.

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