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EAMIRSA: a combination of techniques for improving middle skull base surgery.

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Corresponding Author:	Arianna Di Stadio Universita degli Studi di Perugia Perugia, PG ITALY
Corresponding Author's Institution:	Universita degli Studi di Perugia
Corresponding Author E-Mail:	ariannadistadio@hotmail.com
Order of Authors:	Arianna Di Stadio
	Giampietro Ricci
	Franco Trabalzini
	Laura Dipietro
	Puya Dehgani Mobaraki
	Antonio della Volpe
	Luca D'Ascanio
	Jean Jacques Magnan
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Dear Editors,

We want to propose to JoVe our technique EAMIRSA that we use for treating the vascular impingement of the Angle Ponto Cerebellum (APC) and the Internal Auditory Canal (IAC) and we think that by showing it to your readers we can share in the best way our method.

Several techniques have been proposed for treatment of lesion of APC in human, unfortunately the most of that have a high risk of post-surgery sequalae.

EAMIRSA combines two techniques by profiting of the strength of both and by reducing the risks due to the weakness of each method.

We show in this step by step dissection, the correct way to perform the surgery for teaching easily our audience.

We think that JoVe is the best journal for sharing our technique.

We hope that you can appreciate our work

Thank you in advance

Best Regards

Arianna Di Stadio

TITLE:

The Endoscope-Assisted Minimally Invasive Retro-Sigmoid Approach (EAMIRSA): A Combination of Techniques for Improving Middle Skull Base Surgery

AUTHORS & AFFILIATIONS

Arianna Di Stadio[1], Giampietro Ricci[1], Laura Dipietro[3], Puya Dehgani Mobaraki[1], Franco Trabalzini[1,2], Antonio Della Volpe[1,4], Luca D'Ascanio[1,5], Jean Jacques Magnan[1]

[1] Permanent Temporal Bone Dissection Laboratory, University of Perugia, Perugia, IT
[2] Meyer Children Hospital, Otolaryngology Department, Florence, IT
[3] Highland Instruments, Cambridge (MA), USA
[4] Santobono Children Hospital, Otolaryngology Department, Cochlear Implant Unit, Naples, IT
[5] Ospedale Civile of Mantua, Otolaryngology Department, Mantua, IT

Corresponding Author:
Arianna Di Stadio, (ariannadistadio@hotmail.com)

Email Addresses of Co-Authors:

Giampietro Ricci	(giampietro.ricci@unipg.it)
Franco Trabalzini	(francotrabalzini@gmail.com)
Puya Dehgani Mobaraki	(dehganipuya@gmail.com)
Laura Dipietro	(laura.dipietro@gmail.com)
Antonio Della Volpe	(antoniodellavolpe@yahoo.it)
Luca D'Ascanio	(l.dascanio@gmail.com)
Jean Jacques Magnan	(jypmagnan@gmail.com)

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Hemifacial spasm, Tinnitus, Neurovascular conflict, Minimally invasive surgery, Retro-sigmoid approach, Endoscopic surgery, Nerve decompression, Quality of life

SHORT ABSTRACT:

The endoscope-assisted minimally invasive retro-sigmoid approach (EAMIRSA) is a surgical technique that can be used for the treatment of the cerebellopontine angle (CPA) and internal auditory canal (IAC) disease. Here, we describe the material necessary to perform EAMIRSA and illustrate the technique using a step-by-step cadaver dissection.

LONG ABSTRACT:

EAMIRSA is a surgical technique that can be used for the treatment of the cerebellopontine angle (CPA) and internal auditory canal (IAC) diseases, as well as for treating schwannoma, for decompression surgeries (*e.g.*, loops of the anterior inferior cerebellar artery (AICA)), and for the vestibular neurectomy in patients with invalidating vertigo. This technique combines the use of an endoscope and a microscope; the former allows a perfect view of the surgical area (CPA, IAC, and brain structures) and the latter ensures safety of the surgery maneuvers. The use of a minimally invasive approach reduces post-surgery headaches and the risk of a Cerebrospinal Fluid

(CSF) leak. Our group successfully used EAMIRSA during decompression procedures for treating a hemi-facial spasm and tinnitus. Results were satisfactory in terms of function recovery. Sequelae and surgical complications were observed in less than 1% of patients. In acoustic schwannoma surgery, facial nerve damage was observed in less than 1% of cases and the recurrence rate was 0.3%. This article describes the material necessary for performing EAMIRSA and illustrates the technique using a step-by-step cadaver dissection.

INTRODUCTION:

Surgical approaches to the cerebellopontine angle (CPA) and internal auditory canal (IAC) are associated with high risks due to a limited view of the target areas. Techniques that totally rely on endoscopy have been proposed[1,2], but the high risk of facial nerve sequelae[1], significant learning curves, and the need for a third hand for maintaining the endoscope in position [2] have limited their applicability.

The endoscope-assisted minimally invasive retro-sigmoid approach (EAMIRSA), originally proposed in 1976[3], was further developed in 1993[4] by Magnan, who used this approach for endoscope-assisted surgery. The technique was improved by combining a microscope and an endoscope to safely treat neurovascular conflicts in the CPA/IAC[5]. Furthermore, different from the totally endoscopic transpromontorial approach[1], the retrosigmoid route allows a total preservation of the cochlea and labyrinth[2-6]; this combined approach reduces the risks that are typically associated with approaches that rely on an endoscope only or a microscope only. EAMIRSA's major advantage lies in the use of the endoscope, which allows a 360° view and thus a complete visualization of the structures' relative positions[6-8]. Additionally, the endoscope allows a minimally invasive approach that reduces the risk of persistent headaches and cerebrospinal fluid (CSF) leak, which are common major complications of this type of surgeries[9].

The endoscope improves visibility of the structures' relative positions as the instrument goes inside the surgical area, thereby allowing the surgeon to investigate CPA anatomy via careful movements of the surgical instruments. This improved visualization eliminates the need for the extended craniotomy (commonly performed in CPA surgery to increase visibility and eliminate "blind" angles).

In EAMIRSA, the endoscope is first used to view and inspect the target area, which is then dissected with two hands under microscope vision[6,7]. EAMIRSA can be used in the treatment of different CPA and IAC diseases, schwannoma removal[10], and surgical decompression of cochlear[6] or facial nerves[7]. It has been proven to increase both the short and long-term surgical outcomes with a very low incidence (<1%) of major sequelae[5-8].

In this article, we describe the material necessary for performing EAMIRSA and illustrate the technique using a step-by-step cadaver dissection.

PROTOCOL:

This study was approved by the Human Ethic Committee of University Hospital of Perugia and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. The sample was represented from subject over 18 years, with equal sex distribution.

1. Preparation of the Patient

1.1. Set up the operating room as shown in **Figure 1**. Place the patient on the surgical table and connect the anesthesia monitoring system.

1.2. Anesthesia

1.2.1. Pre-medicate with 1-2 mg of Lorazepam Oral intravenously or with 2-4 mg of Lorazepam Oral if using oral suspension.

1.2.2. 5 to 15 min after premedication, induce general anesthesia by combining drugs for total intravenous anesthesia (TIVA) such as Propofol, short-acting opioid, and low- to-moderate levels of inhalational agents[11].

1.3. Intubation

1.3.1. When the patient sleeps, open his/her mouth with the dominant hand by placing a thumb on the lower jaw and the middle finger on the upper jaw. Extend the patient's neck.

1.3.2. Open the laryngoscope blade and insert it into the patient's mouth. Slowly advance the blade along the tongue dorsal surface until the tip of the epiglottis and the vocal folds is seen.

1.3.3. Under the direct vision of the glottic plane, insert an armed endotracheal tube for intubation.

1.3.4. To conclude this procedure, attach the endotracheal tube to the automatic respiratory machine[12].

NOTE: This armed endotracheal tube is preferred in order to avoid possible occlusions and narrowing caused by inappropriate jaw contractions by the patient due to stimulation of the cranial nerves in the surgical area[13].

1.4. Surgical Preparation of the Patient

1.4.1. Cut the patient's hair 6-8 cm posterior to the ear with a sterile scalpel.

1.4.2. Turn the patient's head to the side contralateral to the surgical site. Disinfect the skin of the surgical area with a sterile gauze imbibed with iodine-based scrub or chlorhexidine solution and grabbed with sterile gloves; repeat this step at least twice.

1.4.3. Turn the patient head from the lateral position to a frontal position and stabilize him/her in supine position.

NOTE: The head must be turned to the side opposite to the surgical side (45°-60°), with a small flection of his/her head and chin near the clavicle.

1.4.4. Protect the patient's eyes with a lacrimal gel and close the eye with a bilateral ocular bandage. Place electrodes for facial monitoring 1 cm from lateral cantus and 1-2 cm from the mouth angle (**Figure 2a**).

1.4.5. Change the sterile gloves with new ones. By using 4 sterile drapes prepare a sterile area that includes the posterior part of the ear and the mastoid area following the best practice guidelines[14, 15].

1.4.5.1. Start by placing the first drape covering the face, the second one covering the patient's hair, the third covering the neck and the last one posteriorly to the mastoid area.

1.4.5.2. Finally cover the field with transparent sterile adhesive surgical patch (**Figure 2b**).

2. Surgical Technique

2.1. Skin and Muscle Time

2.1.1. With a dermographic pen, draw the proposed incision line in the retro-auricular area (**Figure 2c, and Figure 3**).

2.1.2. Inject 5-7 mL of 2% lidocaine with 1: 100,000 epinephrine solution using a 5 mL syringe.

2.1.3. With a cold scalpel (No 11), perform a skin incision of 6-8 cm with an arciform shape. Make the incision with a convex side facing backwards, about 1 cm behind the supposed posterior edge of the craniotomy and 2 fingers behind the helix projection on the retro-mastoid region.

2.1.4. With an electric scalpel, elevate an anterior skin flap. Perform a muscle-periosteal incision with posterior convexity with a monopolar scalpel (**Figure 4a**).

2.1.5. Insert a Beckman orthostatic retractor. Expose the posterior edge of the mastoid in the posterior part of the surgical field, the digastric groove that is under the ear lobe, and the mastoid emissary vein, which bleeds more than the surrounding areas. Coagulate the mastoid emissary vein (**Figure 4b and 4c**).

NOTE: From now on, the surgical procedures are performed under microscope vision adjusting the magnification (from smaller to higher) to clearly see the anatomical structures.

2.1.6. Grab the sterile microscope for otoneurosurgery with two hands and place it close to the operatory area. Focus the microscope by using 1X magnification and adjust it until the operatory area is perfectly in the center. Then use 1.6X magnification to start the bone time.

2.2. Bone Time (Figures 5a, 5b, 5c, 5d)

2.2.1. Take the drill with a large cutting burr and perform a circular craniotomy of 1.5- 2 cm in diameter posterior to the sigmoid sinus using its emissary vein as a landmark.

NOTE: The sigmoid sinus emissary vein is a synonymous of mastoid emissary vein.

2.2.2. Start the dissection with a large cutting burr; then, use a diamond burr when the dura and the sigmoid sinus is approached to preserve their surfaces. Perform the drilling until the sigmoid sinus is completely exposed, leaving a very thin bony shell over it to preserve the venous structure.

NOTE: The sigmoid sinus is the posterior limit of the mastoidectomy area. One can identify it by listening to the sound of the drill during the procedure: the sound of the cutting burr during drilling will become metallic when in contact with the sinus. Change the cutting burr with a diamond one when the sound changes.

2.2.3. After exposing the sinus, remove the hard bone from its posterior surface. When only a thin bony shell remains, use a micro bone-dissector to remove the bone without injuring the dura.

2.2.4. Preserve the bone dust that comes out from drilling by collecting it with a spatula and then by putting it in metallic bowl until the closure time.

2.3. Dura Time (Figures 6a, 6b, 6c)

2.3.1. Before this step, ask all the members of the surgical team to change their sterile gloves.

NOTE: During this surgical step, ask the anesthesiologist to increase the dose of general sedation for increasing the depth of the patient’s sleep.

2.3.2. With a micro-scalpel open the dura with a V shape incision, starting just behind the sigmoid sinus to reduce the need for cerebellar mechanical retraction during the access to the IAC.

NOTE: The dura incision needs to be performed without touching the brain and 1-2 mm from the craniotomy edges in order to facilitate dura re-suturing at the end of surgery.

2.3.3. Perform the dura hemostasis by holding the bleeding point with a bipolar coagulator forceps and then coagulating by 1-2 shots. After that, fasten the dura to the adjacent tissues with a silk suture.

2.3.4. Ask the anesthesiologist to gradually dehydrate the patient by administering 1 g/kg mannitol and by hyperventilation leading to an arterial pCO_2 between 25 to 32 mmHg, which reduces CSF intra-cranial pressure and causes a spontaneous retraction of the cerebellum.

2.3.5. Place a thin neurosurgical micro-cotton or surgical substitute of dura (1.5 cm x 5 cm) over the cerebellum.

2.4. Cerebellopontine Angle (CPA) Approach by Using a Microscope (Figure 6d, 6e, 6f)

2.4.1. Grab a small piece of cotton patch with a micro clamp without teeth and gently compress the cerebellum posteriorly.

2.4.2. With micro-scissors, open the cisterna magna to complete the access to the CPA. Use an aspirator with hand-suction control.

2.4.3. Under microscope view, dissect the arachnoid surrounding the cranial nerves (acoustic-facial bundle) and around the lower cranial nerves with a smooth micro-dissector.

2.5. Endoscopy Time

NOTE: This surgery step lasts about 30 min. (**Figure 7a-7b**)

2.5.1. Carefully insert a rigid 30° endoscope directing downwards to visualize the CPA.

2.5.2. In the center of the surgical field, first identify the acoustic-facial bundle (central landmark of the CPA) as a group of nerves running from the cerebellum towards the IAC. Then identify the area where the vessel(s) is(are) direct contact with the bundle causing the neurovascular conflict (NVC).

2.5.3. Inspect the area around the facial-acoustic bundle using the 360° view allowed by the endoscope (**Figure 8a, 8b, 8c**).

2.5.4. During this procedure, that takes about 5 min, periodically take out the endoscope from the field and clean its tip by touching it with the cotton patch (this maneuver will help cool down the endoscope's light); then re-introduce the endoscope into the surgical field.

2.6. Microvascular decompression under microscope with endoscope assistance (Figure 7c, 7d, 7e)

2.6.1. Take a smooth round micro-dissector and gently separate the vessel (offending) that is attached to the nerve involved in the microvascular compression.

NOTE: The most common offending vessel is the posterior inferior cerebellar artery (PICA) followed by the anterior inferior cerebellar artery (AICA).

2.6.2. 2.6.2. If the offending vessel juts in the first portion of the IAC, drill this bony wall with a very small diamond burr to free the nerve completely.

NOTE: The drilling direction is from the CPA (behind) to the temporal bone (posterior to anterior). During the procedure, drill away only 1-3 mm of bone to prevent damage to the endolymphatic structures (sac and/or duct). It is important to follow the nerve direction to identify the IAC bony wall.

2.6.3. If the loop causing the nerve compression is due to a vein, after vessel detachment, coagulate the vein by using 1-2 shots of bipolar forceps coagulator.

2.6.4. Grab a polytetrafluoroethylene sponge with a micro-Hartman alligator forceps and insert the sponge between the offending artery(ies) and the nerve (facial/cochlear/ vestibular) to prevent impingement recurrences.

2.6.5. Move the sponge using a micro-dissector until an appropriate and stable position is reached.

NOTE: The position where no part of the vessel remains in contact with the nerve is considered as an appropriate position. The sponge needs to restore the normal facial-acoustic bundle anatomy, where vessels run close to the nerve(s) without crossing or touching it/them.

2.6.6. At the end of the microvascular decompression, use the endoscope to check the sponge perfectly divides nerve(s) and vessel(s) and to double-check the result of the decompression by orienting the endoscope upwards so as to properly visualize the vertebral artery that may cause further impingement of the nerves.

2.7. Closure (Figure 9A-9E)

2.7.1. With a micro-Hartman alligator forceps remove the neurosurgical micro-cotton from the surgical area and wash the CPA area with abundant saline solution with a syringe.

Note: Abundant irrigation is needed to remove residual blood cloths.

2.7.2. Hold a piece of dura substitute with micro-Hartman pliers and place it to fill the posterior cisterna.

2.7.3. With a micro needle-holder, place 6/0 single re-absorbable stitches to close the dura. In order to obtain a waterproof closure, insert some muscular tissue between the stitches and fix it with fibrin glue.

2.7.4. Use a micro-clamp without teeth to place a piece of dura substitute on the dura external surface, then add a slide of absorbable hemostat of adequate size to cover the dura.

2.7.5. With a micro-spatula take the bone dust, preserved during the drilling time, and lay it on the craniotomy area to obtain a homogeneous cover. Then lay some fibrin glue on the top to totally recover and fix the area. Place 2/0 absorbable interrupted sutures to close the muscle-periosteal flap and 3/0 subcutaneous absorbable stitches.

2.7.6. Suture the skin with 2/0 nonabsorbable stitches.

2.7.7. Apply a compression bandage, which will be kept for 4 days.

3. Post Operatory care

3.1. Ask to the anesthetist to remove the endotracheal tube and wake up the patient.

3.2. Prescribe antibiotic treatment with cephalosporins, analgesic and glycerol (if necessary) then send him/her in the intensive care department for 24 h.

3.3. After the patient has come back to the otolaryngology department (24-48 h), test the spontaneous nystagmus by looking at his/her eyes during the finger-following test and evaluate if nerve deficits are present. If the patient is comfortable, ask him/her to walk with the person present in the room.

3.4. After 7 days suspend medical treatments if no complication occurs and discharge the patient to his/her house.

REPRESENTATIVE RESULTS:

EAMIRSA has been successfully used by several surgeons[4-7,9]. Our group has used this technique on patients suffering from facial hemispasm (HFS) due to a vascular loop compression on the VII cranial nerve (facial) and has achieved satisfactory results in the short- and long-term follow-up, including short recovery time, symptom resolution, and absence of immediate post-operative sequelae[7]. Immediately after surgery, patients display a reduction of HFS intensity, and in 75% of cases the spasm completely disappears within 24 hours after surgery[7]. Intraoperative facial monitoring shows immediate improvement of signal transmission when the vessel is detached and the nerve is freed, demonstrating the efficacy of the decompression maneuver.

We routinely use EAMIRSA to perform vascular decompression on patients that display a vascular compressive syndrome on the VIII cranial nerve (cochlear)[6] and related invalidating tinnitus not responsive to pharmacological treatment. In these cases, we use auditory brainstem response (ABR) and pure tone audiometry (PTA) testing prior and following surgery. ABR testing allows functional investigation of the hearing pathways from the nerve to the cortex and is used to confirm the diagnosis of nerve compression syndromes as well as to quantify the effectiveness of the decompression procedure. Increase in latency and amplitude of ABR waveform after surgery indicates good signal transmission within the cochlear nerve (**Figure 10**). PTA is used to quantify how conservative the EAMIRSA technique has been (and thus to assess to which extent hearing function has been preserved[6]) (**Figure 11**).

Figure 12 shows a vessel compressing the cochlear nerve (**Figure 12A**, microscopic view) and the facial nerve (**Figure 12B**, endoscopic view). **Figure 13** shows the new position of the vessel after it has been detached from the nerve and sponge has been inserted to avoid possible recurrences (caused by the vessel moving back to its original position).

FIGURE AND TABLE LEGENDS:

Figure 1: Organization of operatory room during EAMIRSA.

Figure 2: Patient preparation before surgery. A) shows the position of patient's head before preparation of a sterile surgical field, and the asterisks indicate the position of facial monitoring. B) shows the retro-mastoid area with the posterior part of the ear after sterile preparation. C): the image shows the pattern for minimally invasive retrosigmoid approach (right side). The image shows the anatomic landmarks for the surgical access: 1= Frankfurt plane between the external canthus and tragus superior edge; 2=digastric muscle plane; 3= craniotomy site projection; 4=surgical incision. This figure has been modified with permissions[7].

Figure 3: Comparison between retrosigmoid and minimally invasive approaches. The drawing shows the difference between a standard craniotomy retrosigmoid approach and the minimally invasive one.

Figure 4: Skin and Muscle times. A) Preparation of the cutaneous flap. Infiltration with lidocaine/adrenaline, arciform incision with anterior convexity (7 cm long), flap rising from the tip of the mastoid towards the protuberance occipital (the incision is placed a fingertip behind the posterior rim of the mastoid process). B) Incision of the muscular-periosteal tissue with posterior convexity, elevation of muscular-periosteum flap and exposure of the mastoid area. The surgical field is limited by: the posterior edge of the mastoid, the digastric groove, the mastoid emissary vein which is coagulated and sectioned. C) Retraction of cutaneous and subcutaneous tissues with the periosteal dissector, placement of a Beckman orthostatic retractor. The yellow arrow shows the position of the emissary vein.

Figure 5: Bone Time. A) bone drilling with a large cutting burr on the retro-mastoid area, below the upper occipital curved line, centered on the emissary vein. B) The circular craniotomy performed by diamond cutting burr has a diameter of 1.5-2 cm and is behind the sigmoid sinus. The blue that appears in transparency is the sigmoid sinus wall and represents the anterior limit in this approach (yellow arrow). The dura is then exposed. C) The residual bone fragments are removed with a small periosteum elevator (yellow arrow) or a dura mater dissector. The yellow star indicates the open mastoid cell. D) The bone dust obtained after bone drilling is preserved to be used during the closure time.

Figure 6: Approach to CPA. A) A posterior convexity incision of the dura is carefully performed, after the detachment of bone splinters and closure of the open mastoid cells with Horsley wax.

B) Exposition of the cerebellar lobe. C) Suspension of the dura tissue to adjacent subcutaneous tissues by using silk threads. Protection of the cerebellar lobe with substitute of dura (white). D) Slight compression of the cerebellum by using substitute of dura to visualize the CPA. E) Opening of the cisterna magna: the CSF coming out from the surgical field is removed with hand-control suction (thus increasing cerebellum retraction). F) Release of arachnoid adhesions for a better exposure of the acoustic-facial bundle.

Figure 7: Surgical Decompression. A) and B) Endoscopic views of the neurovascular impingement (different depths). C) Dissection of the contact area between the vessel and nerve. D) Teflon interposition to divide vessel and nerve and avoid recurrence. E) Endoscopic view after nerve decompression.

Figure 8: Endoscope investigation of structures. The images show the vessel and the acoustic-facial bundle from three different points of view.

Figure 9: Closure time. A) Filling of posterior cisterna, insertion of substitute of dura, and closure of the dura by stiches with interposition of glued muscle fragments. B) Insertion of substitute of dura on the external surface of the sutured dura. C) Bone dust glued with fibrin glue and shaped as the craniotomy. D) Apposition of glued bone dust on the craniotomy. E) Closure of skin with interrupted stitches.

Figure 10: Auditory Brain Response. The left and right panel shows ABR recorded prior and after decompression with EAMIRSA, respectively. The red arrow indicates a change in waveform indicative of improvement in electric signal transmission.

Figure 11: Pure tone Test. Results of PTA testing performed on a patient after left cochlear nerve decompression surgery. The auditory threshold in the affected (left) side (x and black line) is similar to that in the normal (right) side (circle and red line), which indicates total preservation of auditory function and absence of intra-operative lesions.

Figure 12: Comparation between microscopic and endoscopic view before surgery. The left panel (A) shows a microscopic view (20 x) of a loop impingement with the cochlear nerve on the left side. The right panel (B) shows an endoscopic view of the Anterior Inferior Cerebellar Artery (AICA) compressing the facial nerve in the Root Entry Zone (REZ) on the right side. This figure has been modified with permissions[7].

Figure 13: Endoscopic versus microscopic view after decompression: Panel A (left ear) and Panel B (right side) show respectively a microscopic view (20X) and endoscopic view of the CPA after surgical decompression surgery and Teflon interposition. This figure has been modified with permissions[7].

DISCUSSION:

Loops in the CPA and IAC ultimately manifest with a number of symptoms/signs, including HFS and tinnitus. In our previous studies[6,7], we quantified the correlation between the loop presence and the occurrence of HFS (or tinnitus) on the ipsilateral side. We also found that in cases where tinnitus was due to a loop impingement involving the cochlear nerve, the minimum caliber of the impinging vessel was 0.8 mm[6].

Traditionally, loops in the CPA and IAC are treated with microvascular decompression (MVD), a technique first introduced by Jannetta and colleagues in 1977[16] specifically for treating vessels impinging on CPA and/or IAC nerves. MVD consists of detaching the offending vascular loop(s) and securing it (them) with a nonabsorbent synthetic sponge with no intentional trauma or disruption of the nerve. Unfortunately, MVD has several limitations, which have led to failures, recurrences, and complications[16-23]. It has been reported that MVD has a mortality rate of 0.2%, and an overall complication rate that ranges from 5% to 25% for temporary dysfunction and from 2% to 10% for permanent neurologic impairment[16-23]. Auditory or facial nerve structures are at high risk of damage: the auditory nerve is reported to be temporary damaged in 3%-5% of cases after surgery, while a permanent damage (hearing loss or deafness) is reported in 2%-3% of cases[12-20]. A facial nerve impairment occurs temporarily in approximately 4% of patients, whereas 1%-2% of patients show permanent facial nerve deficit[16-23].

Precise localization of all nerve-vessel conflicts and confirmation of complete nerve decompression at the end of the procedure are key steps to a successful decompression surgery. However, in MVD, as reported by Jannetta *et al.*[16], the anatomy of the posterior fossa and the limited size of the craniotomy make it difficult to visualize the whole facial nerve course and the porus portion using a microscope only[16-18]. These limitations can be overcome using EAMIRSA, which combines the advantages of microscope with those of endoscope.

Endoscopy allows an excellent direct vision of target structures, but hand movements are limited by the lack of specific neuro-otoendoscopic instruments and the need to hold the endoscope with one hand (which means that surgical maneuvers need to be performed with one hand only). On the other hand, using a microscope during a decompression maneuver allows the surgeon to work in wide areas with two hands, even though the view of the impingement site and neuronal/vascular structures is limited. In EAMIRSA, the combined use of the endoscope and microscope allows one to overcome such limitations. First, the endoscope is used by the surgeon to completely inspect the surgery area and to precisely identify the target structures. Then, during surgery, the endoscope allows the surgeon to minimize hands movements and remove pressure on the cerebellum, thereby reducing the risk of neurological complications. In surgeries that involve decompression of loops in the CPA or loops partially or totally jutting into the IAC, the angled vision offered by the endoscope allows the surgeon to better visualize the impingement site and perform the decompression maneuvers safely. In loops jutting into the IAC, partial drilling of the canal is an additional surgical step needed to completely free the nerve from the conflict. This step increases the surgical space and allows easy detachment of the structures before the final step. Thanks to the endoscope, the surgeon can easily see the position of the vessel relative to the nerve, after which she/he can proceed safely under microscope view and finally insert a small piece of thin polyester urethane sponge between the vessel and the facial or cochlear nerve.

Compared to the microscopic straight linear view (typically used in MVD), EAMIRSA offers a superior vision of the course of the offending vessel thanks to the endoscope (which allows a 360° vision of the surgical field). In particular, the 30° endoscope, which we recommend, offers the best "around-the-corner" visualization of the IAC. Compared to a fully endoscopic surgery, EAMIRSA offers better control of bleeding in presence of anomalous vessels in the CPA, and easy switching to a traditional surgery under microscope in case of emergency.

We previously reported[6,7] that EAMIRSA is a safe and well tolerated procedure[7] without relevant immediate[6] and long term post-operative sequelae[6]. EAMIRSA allowed us to safely and successfully treat HFS and tinnitus without the complications that typically affect the nerves when surgery is conducted under microscope only[16-23]. The patients we operated on with EAMIRSA did not present any neurological complications immediately after surgery and several years post-surgery[7]. EAMIRSA allowed us to perform surgery even on elderly subjects, commonly more at risk of complications than young subjects due to associated comorbidities (*e.g.,* hypertension), without increased postoperative sequelae[7] thanks to the following advantages: a direct view of the nerve-vessel contact, which makes the dislocation of the acoustic-facial bundle and relevant cerebellum retraction unnecessary[24-27]; and a minimally invasive opening window (< 3 cm) in the sigmoid area, which maintains normal intracranial pressure and limits the chance of bacterial infection, thus reducing the risk of CSF leak and of headaches after surgery. Furthermore, EAMIRSA has been successfully used for treating schwannoma[9] with very low complication rates compared to the fully endoscopic technique[28]. Finally, it should be noted that EAMIRSA allows the surgeon to improve her/his skills, especially microsurgery manual dexterity, and knowledge of normal and pathologic anatomy of CPA and IAC, which in turn can help improve management and planning of decompression surgeries.

Limitations of EAMIRSA when used in the CPA include a relative slow learning curve, and risk of structure damage, potentially caused by the use of an endoscope in such small areas. In conclusion, our studies suggest that EAMIRSA is effective for surgeries involving CPA and IAC, and in particular for those aimed at treating vascular impingements in these areas.

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DISCLOSURES:
The authors have nothing to disclose.

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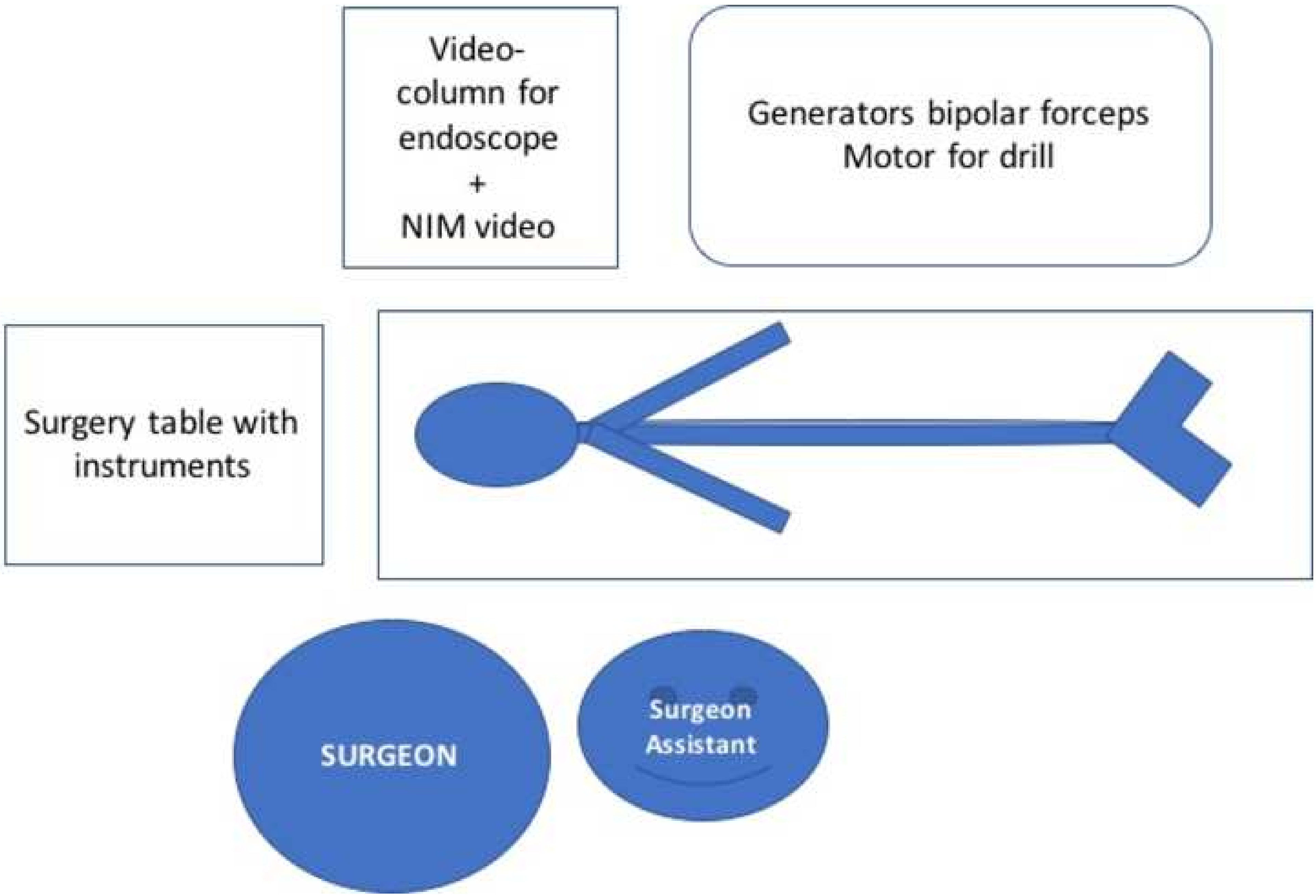
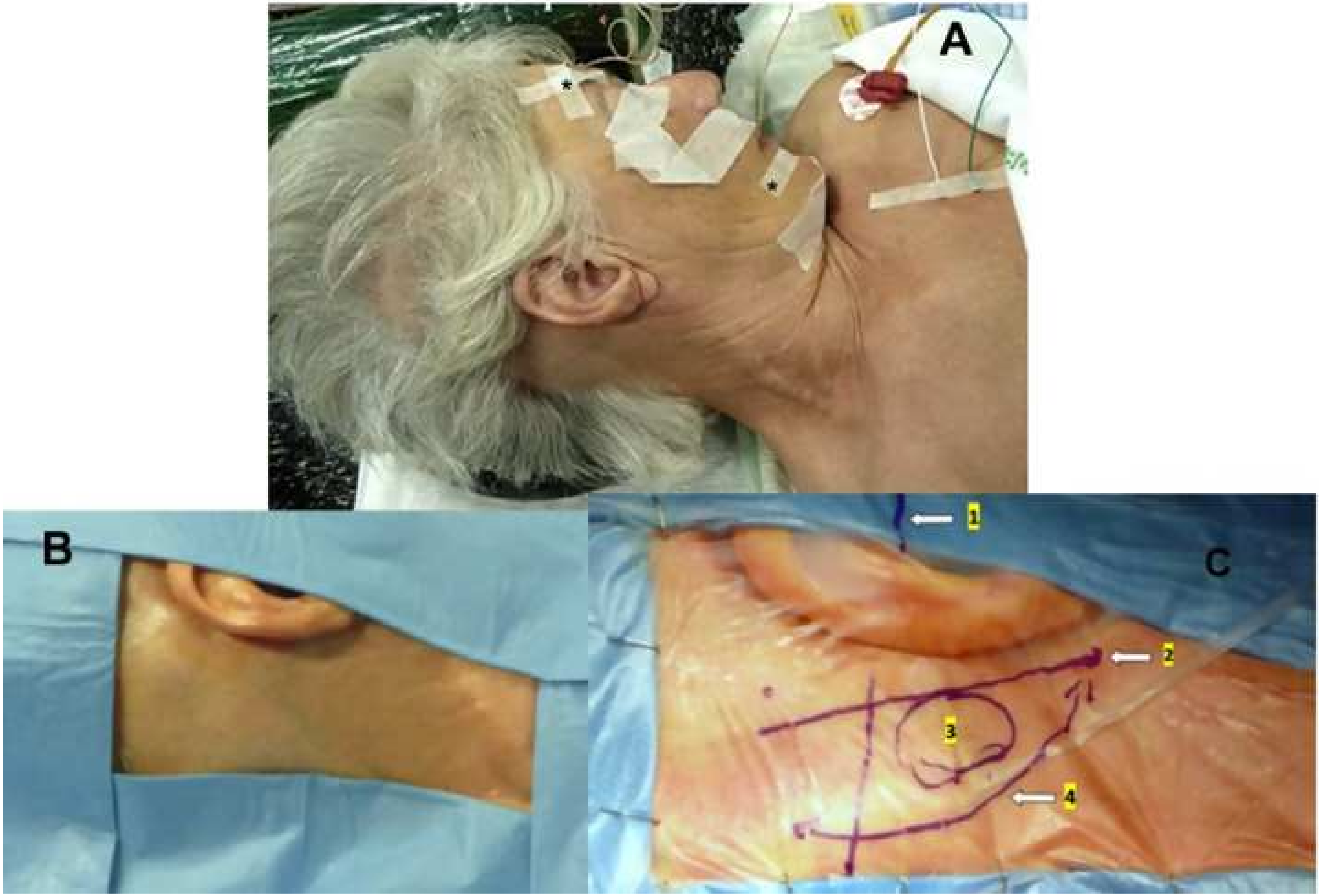
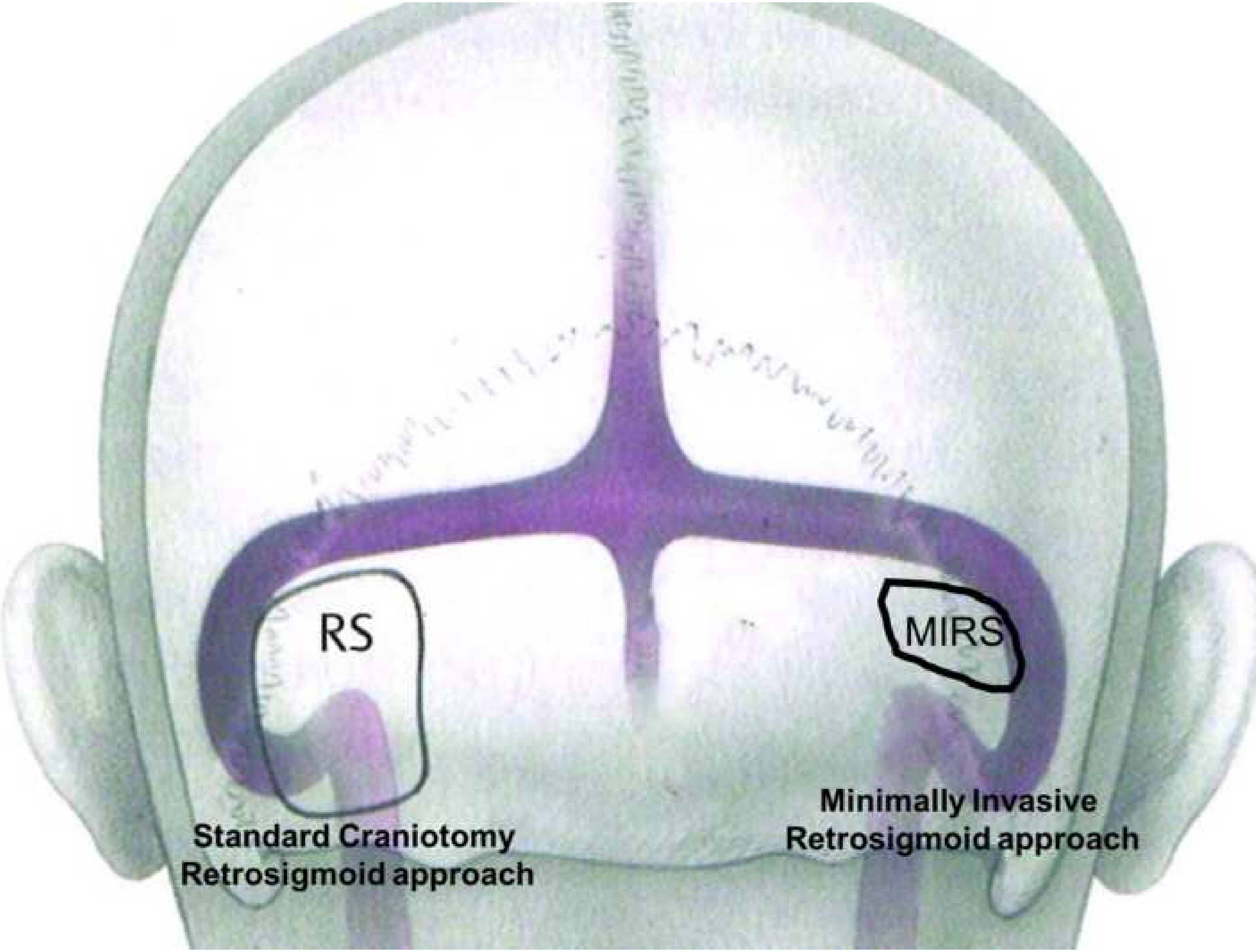

Video-
column for
endoscope
+
NIM video
Generators bipolar forceps
Motor for drill
Surgery table with
instruments
SURGEON
Surgeon
Assistant

Figure

Click here to access/download;Figure;Figure 2.revis2.tiff




RS
MIRS
Standard Craniotomy
Retrosigmoid approach
Minimally Invasive
Retrosigmoid approach

Figure

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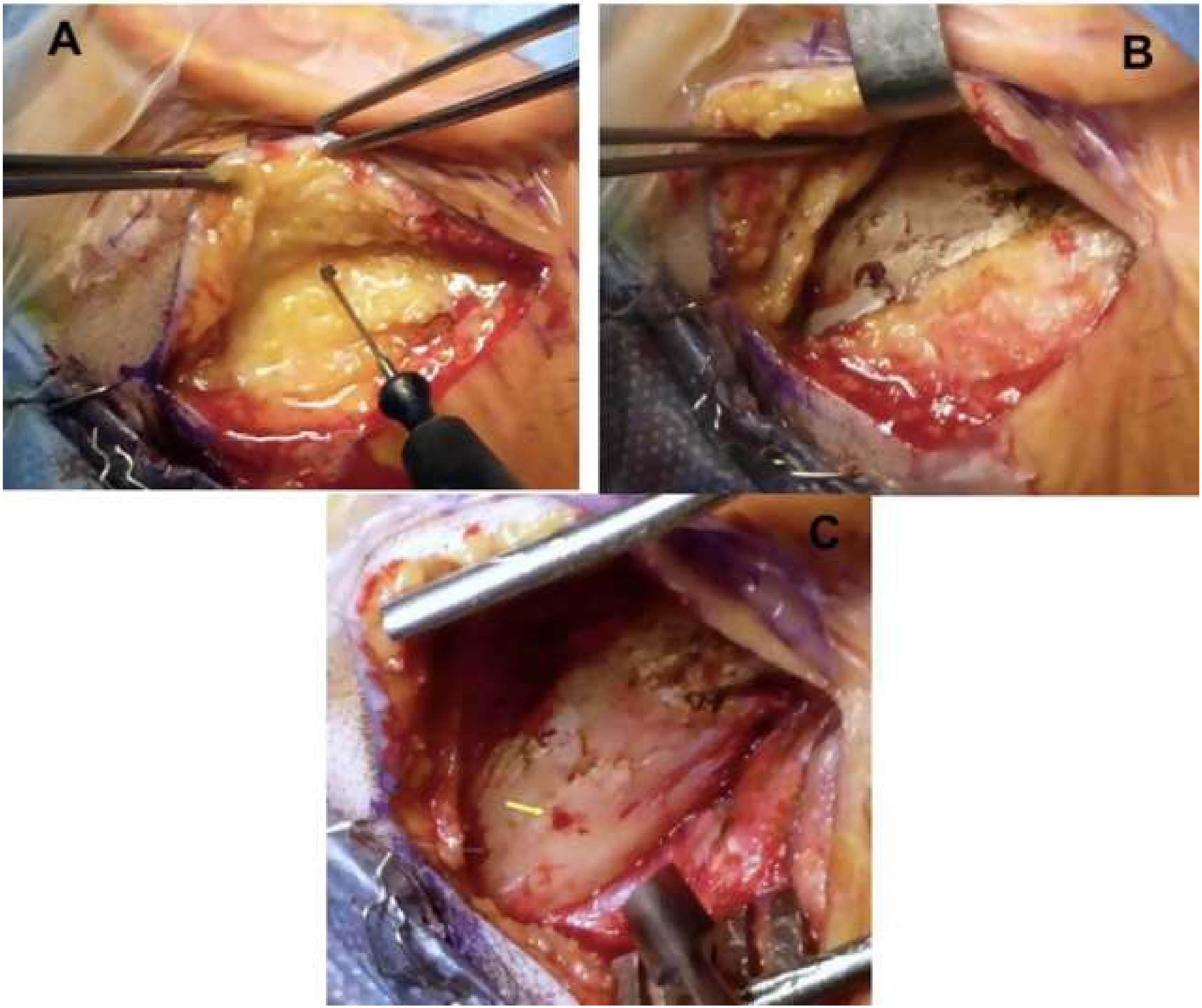

Figure

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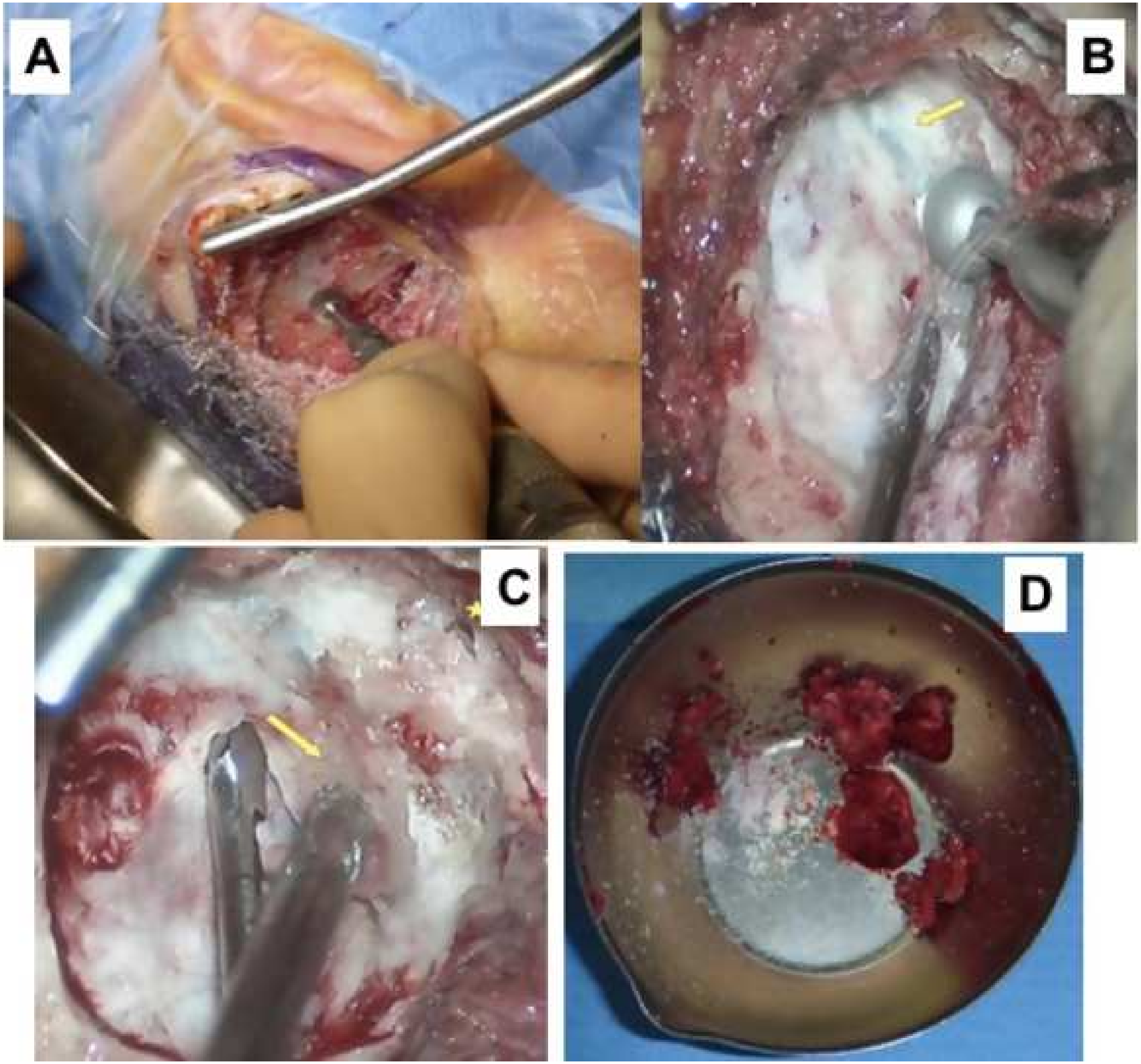

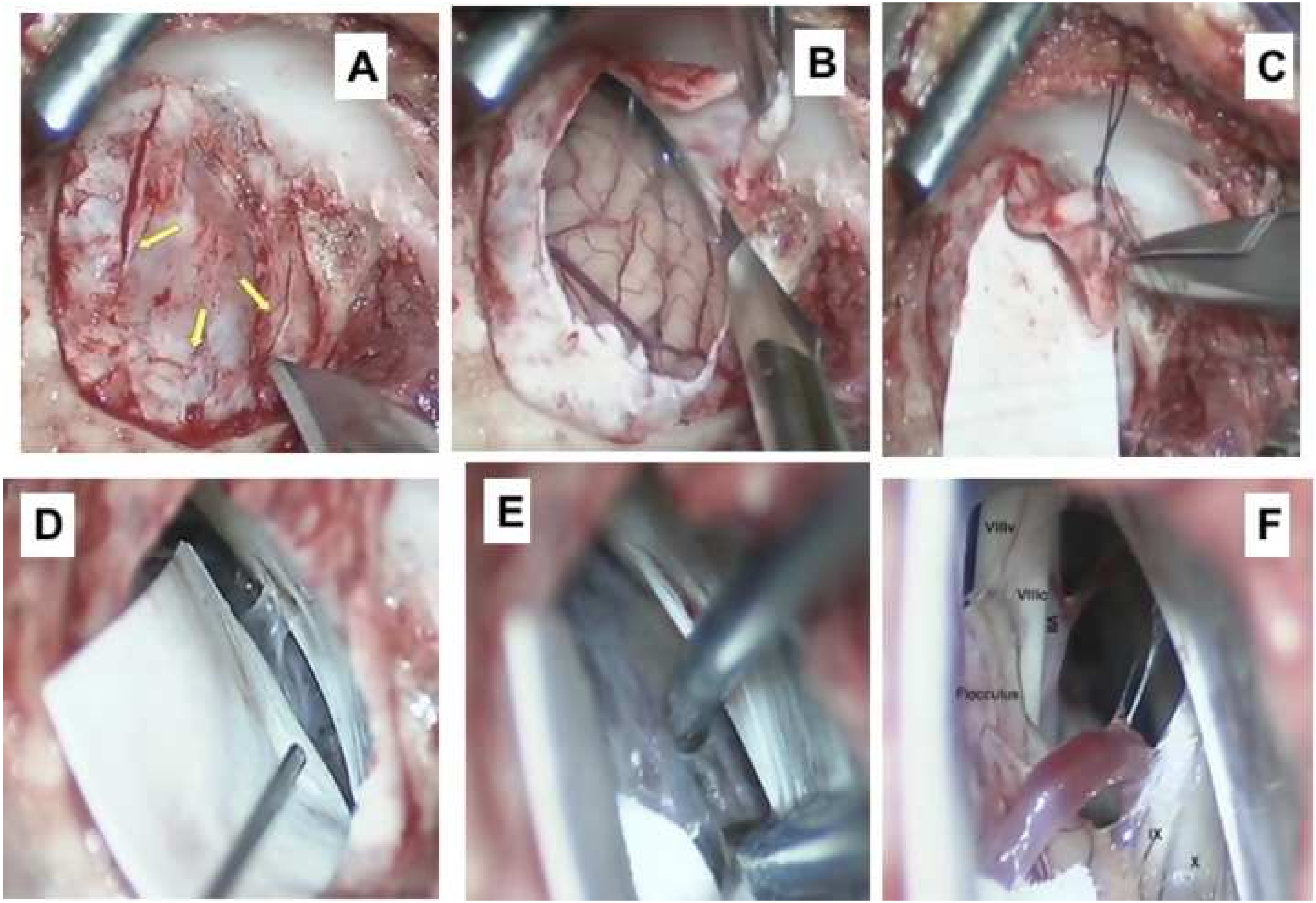
A
B
C
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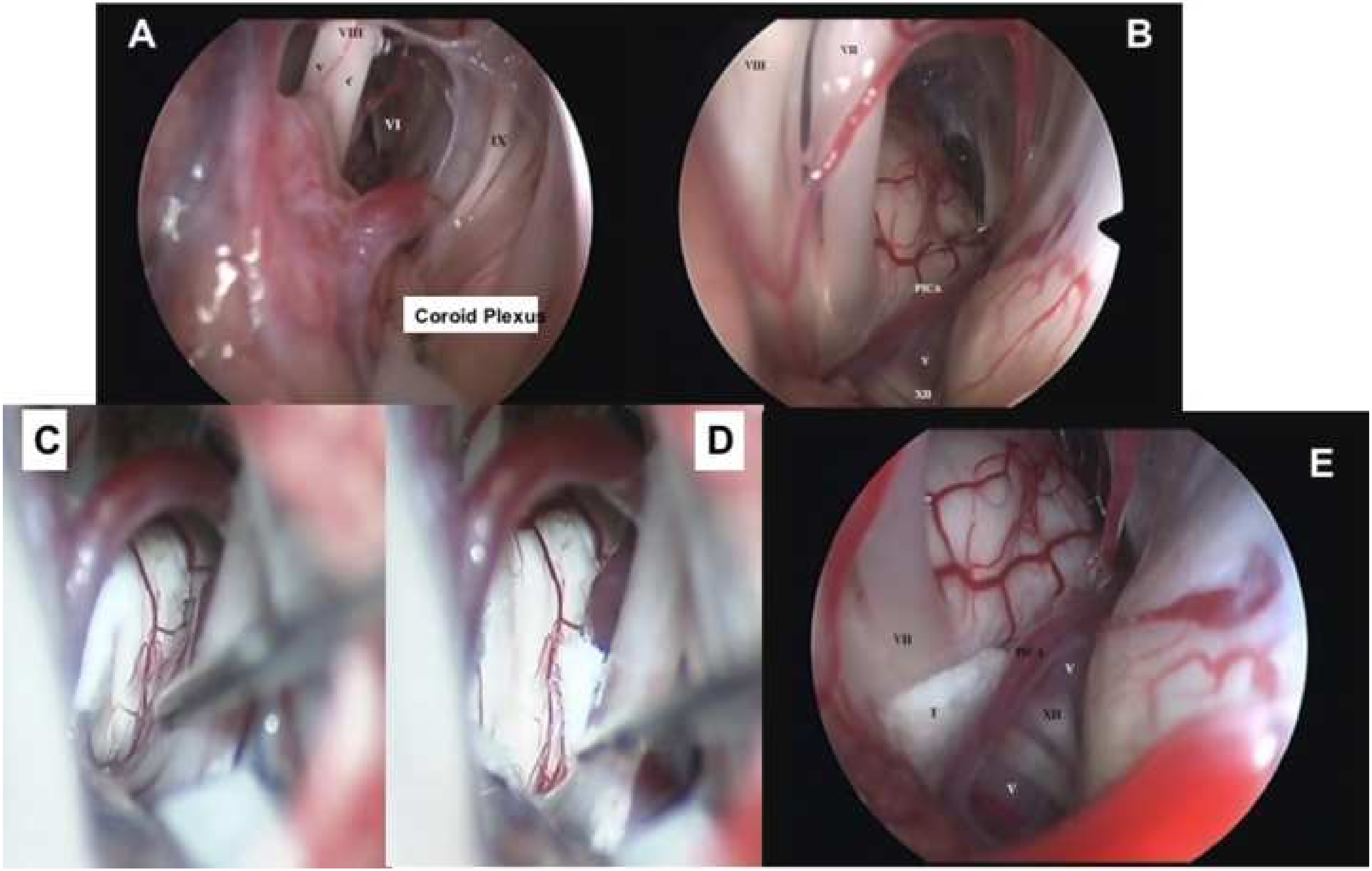
E
F
VIIIv
VIIIc
Flocculus
IX
X


A
VIII
VI
IX
Coroid Plexus
B
VIII
VII
PICA
V
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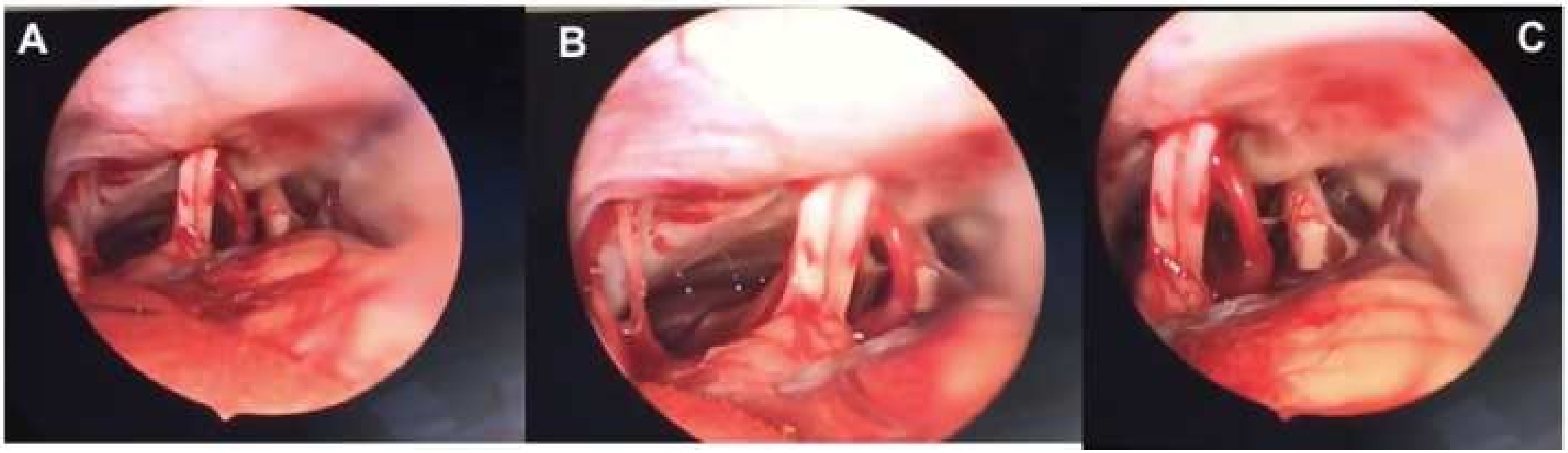
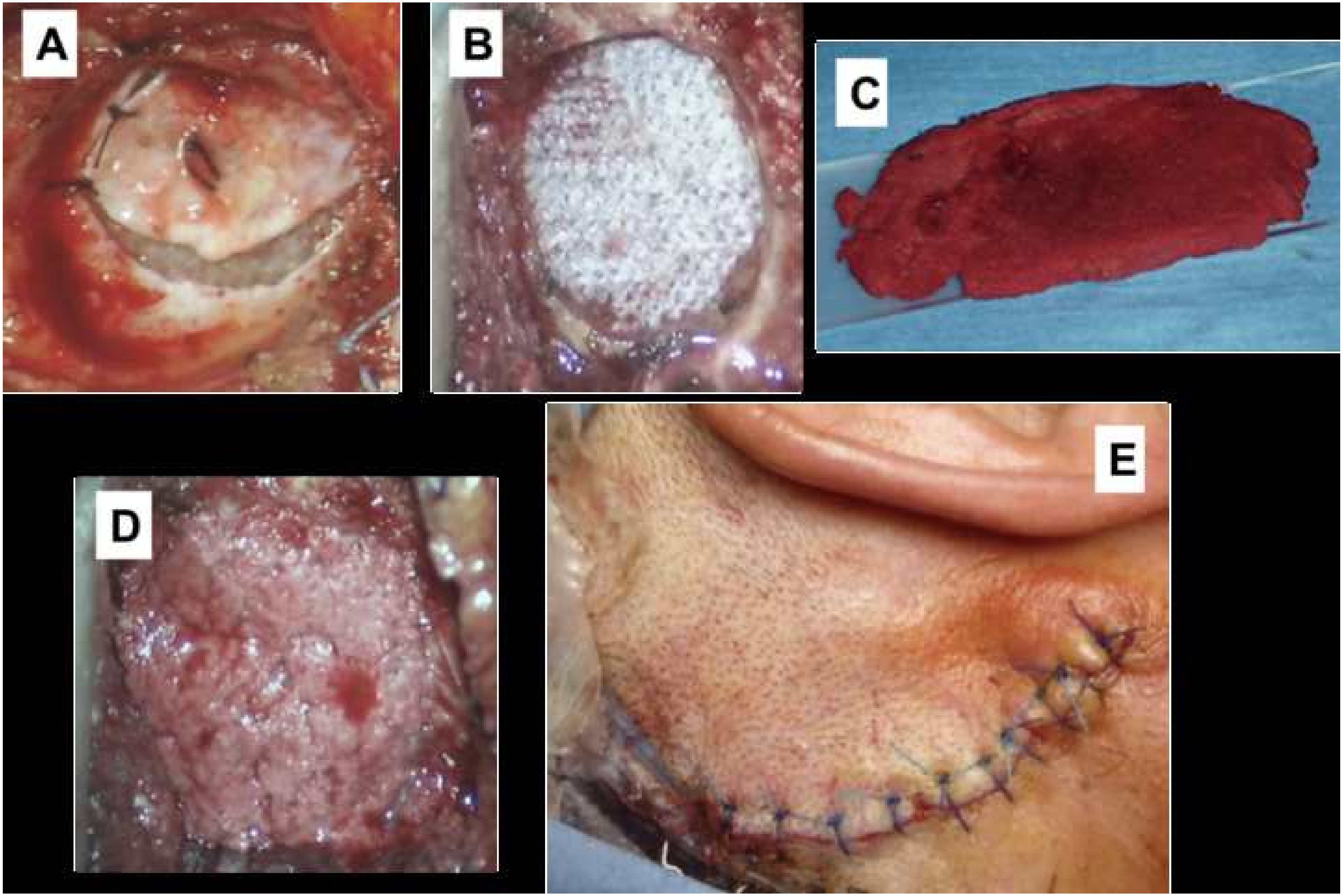
PICA
V
XII
T
V


A
B
C


A
B
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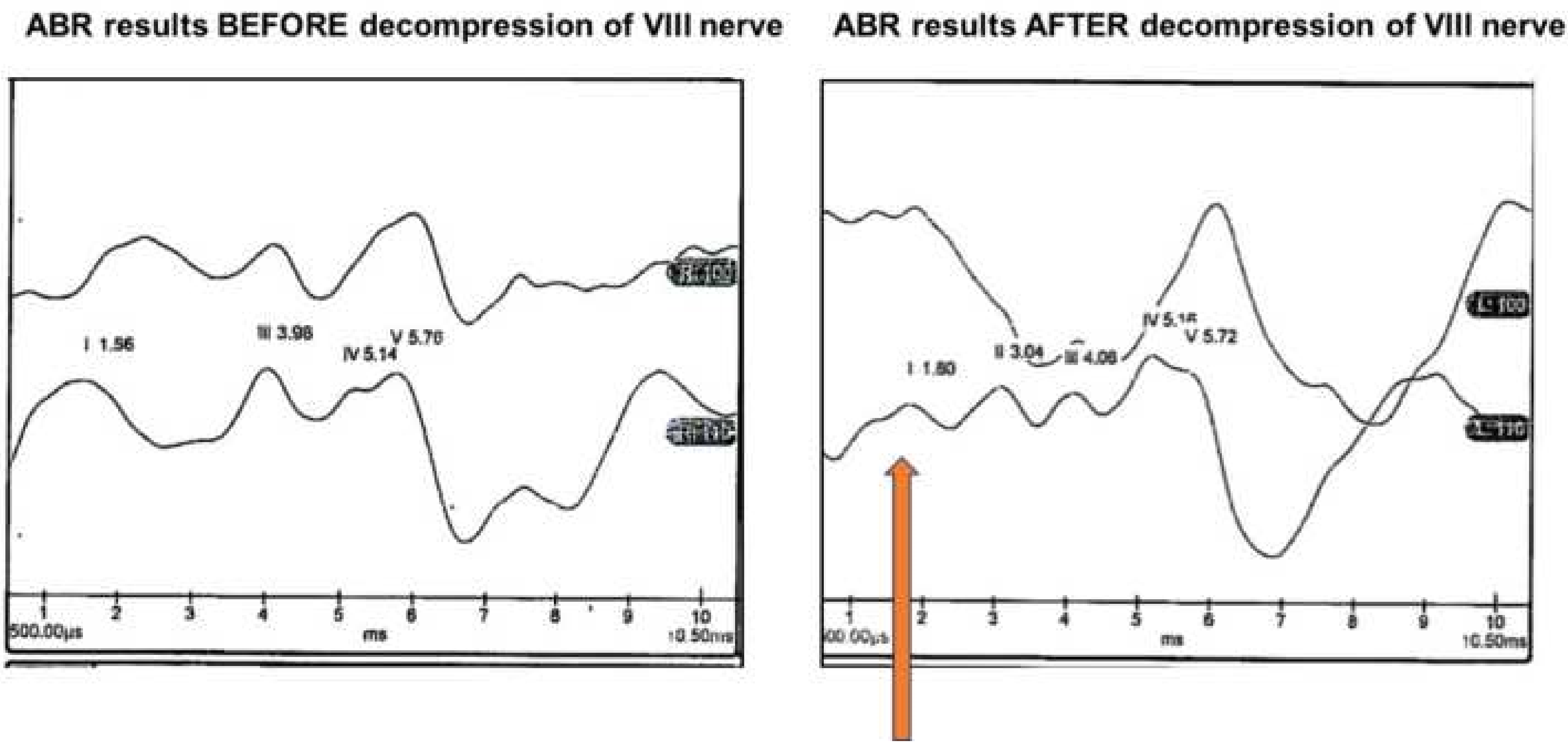
D
E


ABR results BEFORE decompression of VIII nerve
I 1.56
III 3.98
IV 5.14
V 5.76
500.00µs
ms
10.50ms
ABR results AFTER decompression of VIII nerve
I 1.80
II 3.04
III 4.08
V 5.72
ms
10.50ms

Figure

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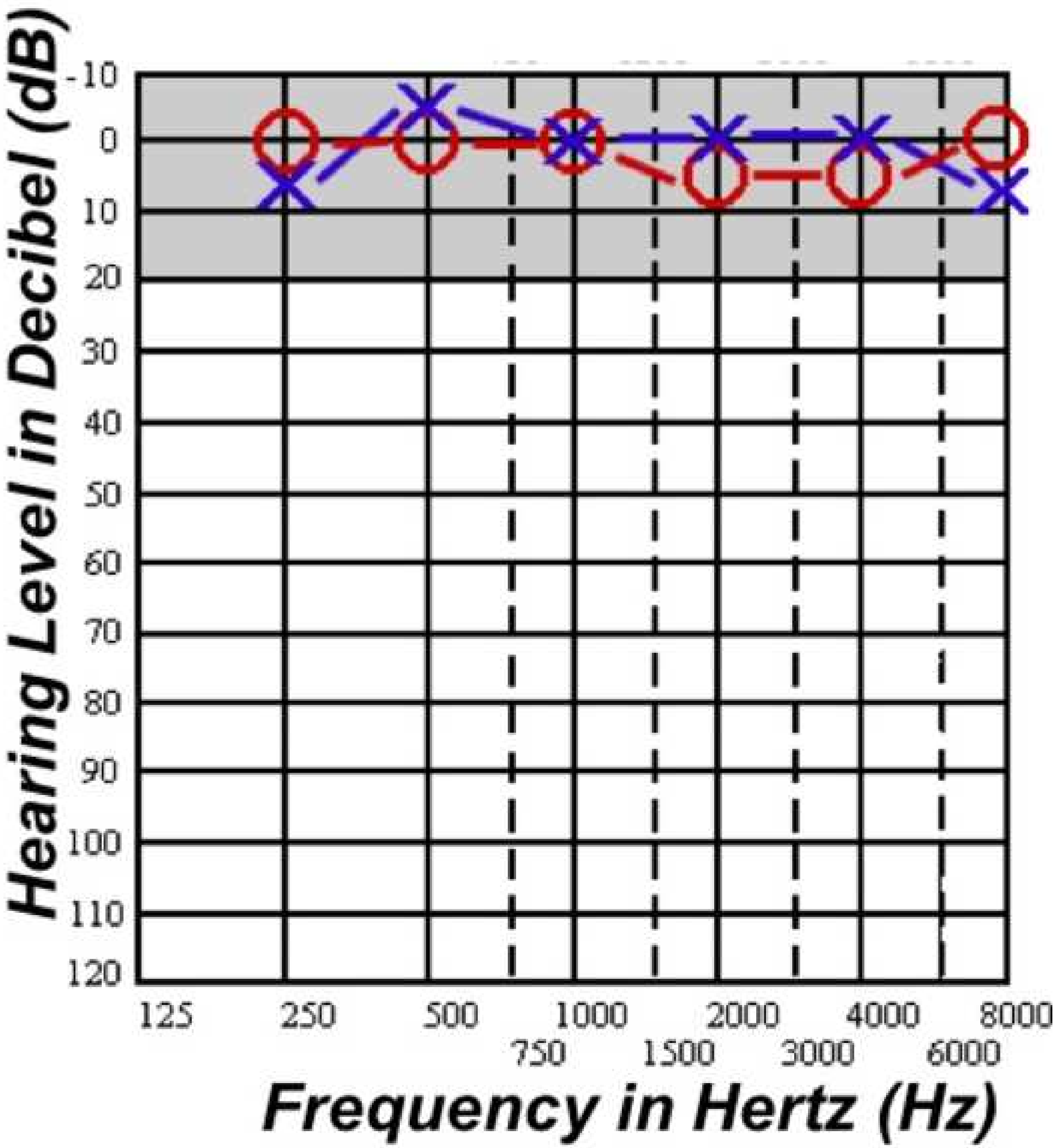
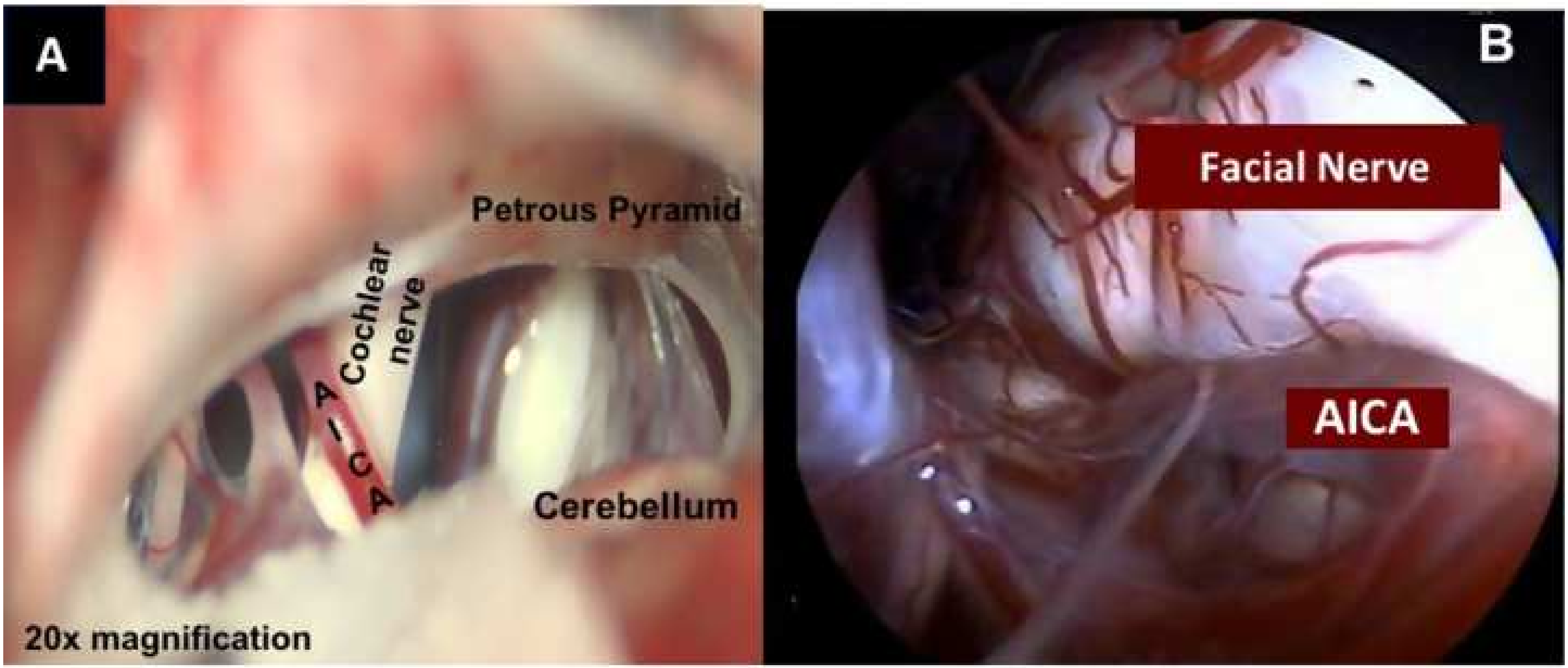
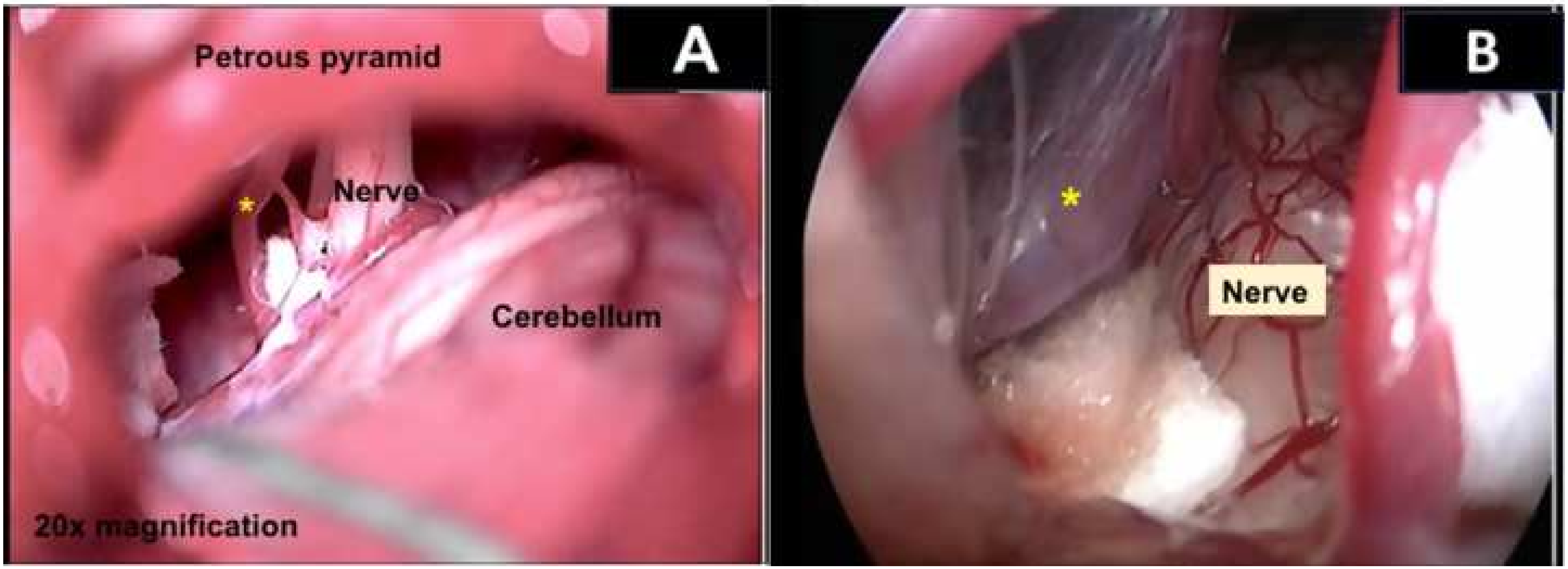



A
Petrous Pyramid
Cochlear nerve
AICA
Cerebellum
20x magnification
B
Facial Nerve
AICA

Figure

Click here to access/download;Figure;Figure 13. a-b.tiff



Name of Material/ Equipment

<u>No Consumable</u>

Facial nerve monitoring system

Video Column

Video Camera

Focal Operatory microscope

Rigid Endoscope 0°

Rigid Endoscope 45°

Drill Stilus Legend

Electric Scalpel DIATERMO MB 380

Aspiration system: 1 continuous and 1 with finger-control

<u>Instruments for the otoneurology approach:</u>

- Stainless cups.

- Large cup warms serum.

Lempert elevator

- Scalpel Handle No. 3, 4, and 7.

- Needle holder: 1 strong, 1 less strong.

- Two pairs of scissors Allaine: 1courbe, 1 right.

-Dissection griffes, foam, De Bakey

- Aspirations:

o Three Fraziers No. 10.12.15.

o Otoneurology suction set: 1 * 2.0, 1 * 1.8; 2 * 1.5; 3 * 1.2 (long); 2 * 1.0.

- Retractors:

o Faraboeuf: 1pair thin, 1 thick pair 12-14 cm

o Auto-static of Wulstein or Beckmann

DRILL BURRS

Micro-instruments of otoneurology:

Fine bipolar forceps Magnan

A pair of scissor Sterkers.

Two pairs of scissors Yasargil (1 right, 1 curve).

Two-surgical forceps (one right, one curve upward).

A dura scalpel

A dura elevator

In case of IAC first: surgical scissors straight strong

Straight instruments:

A hook

A blunt hook.

Two Marquet periostal elevator (1 left, 1 right).

Bayonet instruments

House Hartman

One pointed and sharp hook

Four small periostal elevator (facing up, down, left, right)

Four large periostal elevator (facing up, down, left, right)

Four hooks (facing up, down, left, right)

MORTINI Set

Instruments for otoneurosurgery approach :

Scalpel n°23

Dissection griffes

Wulstein auto-static

Elevator Lampert

Bipolair forceps

Scalpel for dura

Scalpel n°11

Dissection griff DeBakey

Scissor Allaine

Needle holder

Consumable Material

Two suction tubes, with suction cannulas of different sizes.

Operating light handpiece.

Microscope case, camera cover, instrument pocket.

Xomed / Medtronic 2-channel electrode set for monitoring the facial nerve.

Scalpel blades: 22, 11.

Glass scalpel blades.

Surgical gloves and caps

Adhesive surgical (craniotomy pack).

Sterile woven and nonwoven compresses.

Syringe and needle infiltration.

Drugs: 0.5% adrenaline xylocaine, saline, sterile water

Neuropatch

Fibrillar Surgicel

Biological glue 2ml

Horsley Wax

Cottons of neurosurgery cut into various sizes that will be carefully counted (opposit

Teflon cut into various sizes then crushed to be thinned

Lyophilized hardstock or Durapatch Ethisorb Polyglactin 910 / Polydioxanon

Re-absorbable suture

Not-resorbable suture

Urethane sponge

Company	Catalog Number
NIM (Medtronic Jacksonville (FL), USA)	8253002
AIDA, Storz	S-1263
STORTZ	S-1263
ZEISS OPMI SENSERA	S-0607
STORZ	7229 AA
STORZ	7229 FA
MEDTRONIC	1898001
GIMA	30692
TOBI	28234
MILTEX	19-1340
MAYO HEGART	26531
EMEA	Curved : PO144123 ; Straight: PO143282
SURGIWAY	14.1012T
INTEGRA	
INTEGRA	3724218; 3724172; 3724210

INTEGRA	
INTEGRA MEDTRONIC	o-28-8
Cutting	See on productor catalogue
Diamonds	See on productor catalogue
INTEGRA	CP392BI and CP392BS
NOT AVAILABLE	
SKLAR	98-2114
INTEGRA Metzbound	Curved: CP351-3; Straight: CP351-2
STORTZ	28164 EL
STORTZ	663535
INTEGRA	MCO31
INTEGRA	MCO813
INTEGRA	MCO950
INTEGRA	3721036
INTEGRA Causse	MCO657
STORTZ	223982

INTEGRA	MCO224A-2-0
STORTZ	223942; 223943
STORTZ	28164 MDA
INTEGRA MAC INDOE	CP 400 ; CP 407 ;CP 415
INTEGRA	o-28-8
MILTEX	19-1340
INTEGRA	CP392-2R
STORTZ	28164 EL
SURGIWAY	14.1012T
EMEA	Curved : PO144123 ; Straight: PO143282
MAYO HEGART	26531

Medtronic

B/Braun-Aesculap, Tuttlingen, Germany

Braun

TIssucol

:e)

Codman

Bard PTFE

Ethicon

Vicryl

Novafil 2.0

Comments/Description

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CORRESPONDING AUTHOR

Name:	Arianna Di Stadio
Department:	Otolaryngology: Permanent Dissection Temporal Lab
Institution:	University of Perugia
Title:	Researcher
Signature:	Arianna Di Stadio
Date:	23/05/2018

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Editorial comments:

Thanks for your valuable comments and remarks to our paper.
We carefully went through in the main document for satisfying your requests.

Changes to be made by the Author(s):

1. Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammar issues. The JoVE editor will not copy-edit your manuscript and any errors in the submitted revision may be present in the published version.

We corrected the spelling and grammar issues.

2. Please provide figures with higher resolution if possible.

Unfortunately, the figures we provided are the best that we have in terms of resolution, but we improved them as much as possible. We also added additional figures as requested by the reviewers.

3. Figure 1: Please change the font size of "SURGEON" in the circle so that the word is not split across two lines.

We changed the font as suggested.

4. Figure 2: Please move the title in the left panel to the left so that it does not merge with the title in the right panel.

We* moved the title as suggested*.

5. Figure 4: Please label panels a and b in the figure and describe them in the figure legend.

We labeled the panels in figure 4 (now figure 12). We described the structures (different nerves and vessels) in the image itself and in figure legend

6. Please include a scale bar for all images taken with a microscope to provide context to the magnification used. Define the scale in the appropriate figure Legend.

We included a scale bar in both microscope images (i.e. Figures 12.a and 13b. in this revised version of the manuscript). We define the scale in the relevant figure legend.

7. Please revise the title to be more concise.
We revised the title.

8. Please provide an email address for each author.
We added the email address of each author.

9. JoVE cannot publish manuscripts containing commercial language. This includes trademark symbols (™), registered symbols (®), and company names before an instrument or reagent. Please remove all commercial language from your manuscript and use generic terms instead. All commercial products should be sufficiently referenced in the Table of Materials and Reagents. For example: Medtronic ®, Storz ®, Leica ®, Betadine ®, KARL STORZ®, Teflon®, Surgicel®, Vicryl®, Novafil®, Tensoplast®, etc.
We removed commercial language, trademark symbols, registered symbols and company names from the manuscript. We now reference commercial products in the Table of Materials and Reagents.

10. Please adjust the numbering of the Protocol to follow the JoVE Instructions for Authors. For example, 1 should be followed by 1.1 and then 1.1.1 and 1.1.2 if necessary. Please refrain from using bullets, dashes, or indentations.
Thank you. We re-numbered our protocol and removed bullets, dashes, and indentations.

11. Please revise the protocol so that all text in the protocol section is written in the imperative tense as if telling someone how to do the technique (e.g., "Do this," "Ensure that," etc.). The actions should be described in the imperative tense in complete sentences wherever possible. Avoid usage of phrases such as "could be," "should be," and "would be" throughout the Protocol. Any text that cannot be written in the imperative tense may be added as a "Note."
We followed your suggestion and rewrote all the steps in the protocol using the imperative tense only. We removed phrases such as "could be" etc. We included the text that could not be written in the imperative tense in Notes.

12. Lines 75-92: Please either write the text in the imperative tense as if telling someone how to do the technique (e.g., "Do this," "Ensure that," etc.), or move the solutions, materials and equipment information to the Materials Table.
We rewrote the text in lines 75-92 in the imperative tense. We added additional information on equipment that could not be written in the imperative tense as "NOTE, as you suggested.

13. Please add more details to your protocol steps. Please ensure you answer the "how" question, i.e., how is the step performed? Alternatively, add references to published material specifying how to perform the protocol action.
We added more details on our protocol steps as well as new images in an attempt to help the reader to better understand such steps. When including details was not possible, we referenced published material.

14. Lines 96-104, 180-184: These steps do not have enough details to replicate as currently written. Please add more details. For instance, what is the dosage of benzodiazepine, how to induce general anesthesia, and how to prepare a sterile area? Please mention how proper anesthesia is confirmed.
We added details and referenced on the anesthesia protocol and how to prepare a sterile area. We highlighted these steps in yellow so that in the video we can show readers how to prepare a sterile surgical area.

15. For surgical steps, please mention all surgical instruments used in the specific steps.
We added the exact instruments that need to be used in each surgical step.

16. Lines 127-128: Please specify the general sedation method used.
We specified the general sedation method and added references to allow the reader to correctly replicate the procedure.

17. Please include single-line spaces between all paragraphs, headings, steps, etc. After that, please highlight 2.75 pages or less of the Protocol (including headings and spacing) that identifies the essential steps of the protocol for the video, i.e., the steps that should be visualized to tell the most cohesive story of the Protocol.
We followed your suggestions, included single-line spaces between paragraphs, and highlighted 2.75 pages of the protocol for video registration.

18. For in-text references, the corresponding reference numbers should appear as superscripts after the appropriate statement(s) in the text (before punctuation but after closed parenthesis). The references should be numbered in order of appearance.
We inserted the reference numbers as superscripts and numbered references in order of appearance.

19. Please ensure that the references appear as the following: [Lastname, F.I., LastName, F.I., LastName, F.I. Article Title. Source. Volume (Issue), FirstPage – LastPage (YEAR).] For more than 6 authors, list only the first author then et al.
We modified the reference as you suggested.

20. References: Please do not abbreviate journal titles. Please include volume and issue numbers for all references.
We included full journal titles, as well as volume and issue numbers for all references.

21. Please revise the table of the essential supplies, reagents, and equipment. The table should include the name, company, and catalog number of all relevant materials in separate columns in an xls/xlsx file. Please remove trademark (™) and registered (®) symbols from the Table of Equipment and Materials.
We inserted name, company, and catalogue number of all relevant material in separate columns in the material excel file. We removed trademark and registered symbols from the Table of Equipment and Materials.

Answer to Reviewers

We wish to thank the reviewers for their valuable comments.

Reviewer #1 (changes in text are highlighted in light blue)

In this reviewer's opinion, the authors should express the amount endoscopic time during the procedure more clearly.
We added a sentence between parentheses that reports the length of endoscopic time. We inserted a duration time for a surgeon with average level of expertise in

endoscopic surgery of ear and in the EAMIRSA technique.

Furthermore, the authors should explain how the endoscopic visualization might reduce the size of the craniotomy.

We added a sentence that explains the advantages of endoscopic visualization and how it might reduce the size of the craniotomy.

Additionally, the authors should express the learning of using the endoscope.

Thank you for this comment. At the end of our manuscript, we added a sentence that expresses the learning of using the endoscope.

Reviewer #2: (changes in text are highlighted in green)

In this manuscript the authors illustrate how to perform the endoscope-assisted minimally invasive retrosigmoid approach (EAMIRSA) to the Angle Ponto-Cerebellum and Internal Auditory Canal.

1) In the long abstract: "for decompression surgeries (e.g., loops of the ICA)", do you mean AICA?

Thank you. Yes, you are correct. We meant AICA. We corrected this error.

2) In the Figures 3 and 4 the authors could add the side of the approach and name all the different structures, such as the petrous pyramid and the cerebellum to best orient the readers.

In Figures 3 and 4 (which have been renumbered as 12 and 13 in this version of the manuscript) we added the side of the approach and the name of the different structures.

3) It could be helpful to add a figure illustrating the approach step by step, as well as the location and the size of the craniotomy.

We added several figures to better illustrate our approach step-by-step. We illustrated all the steps of our surgical procedure in Figures 1-9. The first figure shows how to position the patient's head for surgery; the last one shows the skin closure step.

4) Some more endoscopic pics could be added in order to illustrate the entire course of the VII-VIII complex, from the brainstem to the IAC.

We added Figure 8 (a,b,c) that illustrates the entire course of the VII-VIII complex, from the brainstem to the IAC.

5) The transcanal transpromontorial approach (Ref. 7 and 22), as the name suggests, relies on a route that is completely different from the retrosigmoid route.

Thank you for this comment. We mentioned the transpromontorial approach because this is the only surgery method that uses a "total" endoscopic treatment. These two references were mentioned to underline the limitations of a full endoscopic approach. To clarify this point we added a small sentence in the introduction.

6) The authors claim that the EAMIRSA reduces the risk of persistent post-surgery headaches and CSF leak. Please, add references.

We added references about the ability of EAMIRSA to reduce post-surgery headaches and CSF leak.

7) Have the authors any tip to safely drill the internal acoustic canal, when required (for example in vestibular schwannoma surgery or for loops jutting into the canal itself), in order to preserve the endolymphatic sac and endolymphatic duct?

We added a sentence that explained how to drill the IAC safely, and to what extent the drill may be extended without touching endolymphatic structures.

Which are their anatomical topographical landmarks?

We used the natural direction of the VII-VIII bundle, and the anatomical angle that these structures follow naturally as anatomical landmarks for drilling the first portion of the IAC.

Have they never used a neuronavigator?

Thank you for this question. No, we never used neuronavigation during this type of surgery. We will keep in mind your suggestion for additional studies that combine EAMIRSA and neuronavigation.

Additional Material

No Consumable

Instruments for the otoneurology approach:

- Stainless cups.
- Large cup warms serum.
- A Lempert rugine.
- Scalpel Handle No. 3, 4, and 7.
- Needle holder: 1 strong, 1 less strong.
- Two pairs of scissors Allaine: 1courbe, 1 right.

-Dissection griffes, foam, De Bakey

- Aspirations:

o Three Fraziers No. 10.12.15.

o Otoneurology suction set: 1 * 2.0, 1 * 1.8; 2 * 1.5; 3 * 1.2 (long); 2 * 1.0.

- Retractors:

o Faraboeuf: 1pair thin, 1 thick pair

o Auto-static of Wulstein or Beckmann

Micro-instruments of otoneurology:

-Fine bipolar forceps.

-A pair of scissor Sterkers.

-Two pairs of scissors Yasargil (1 right, 1 curve).

-Two-surgical forceps (one right, one curve upward).

-A dura scalpel.

-A dura elevator

-In case of IAC first: surgical chisel straight strong.

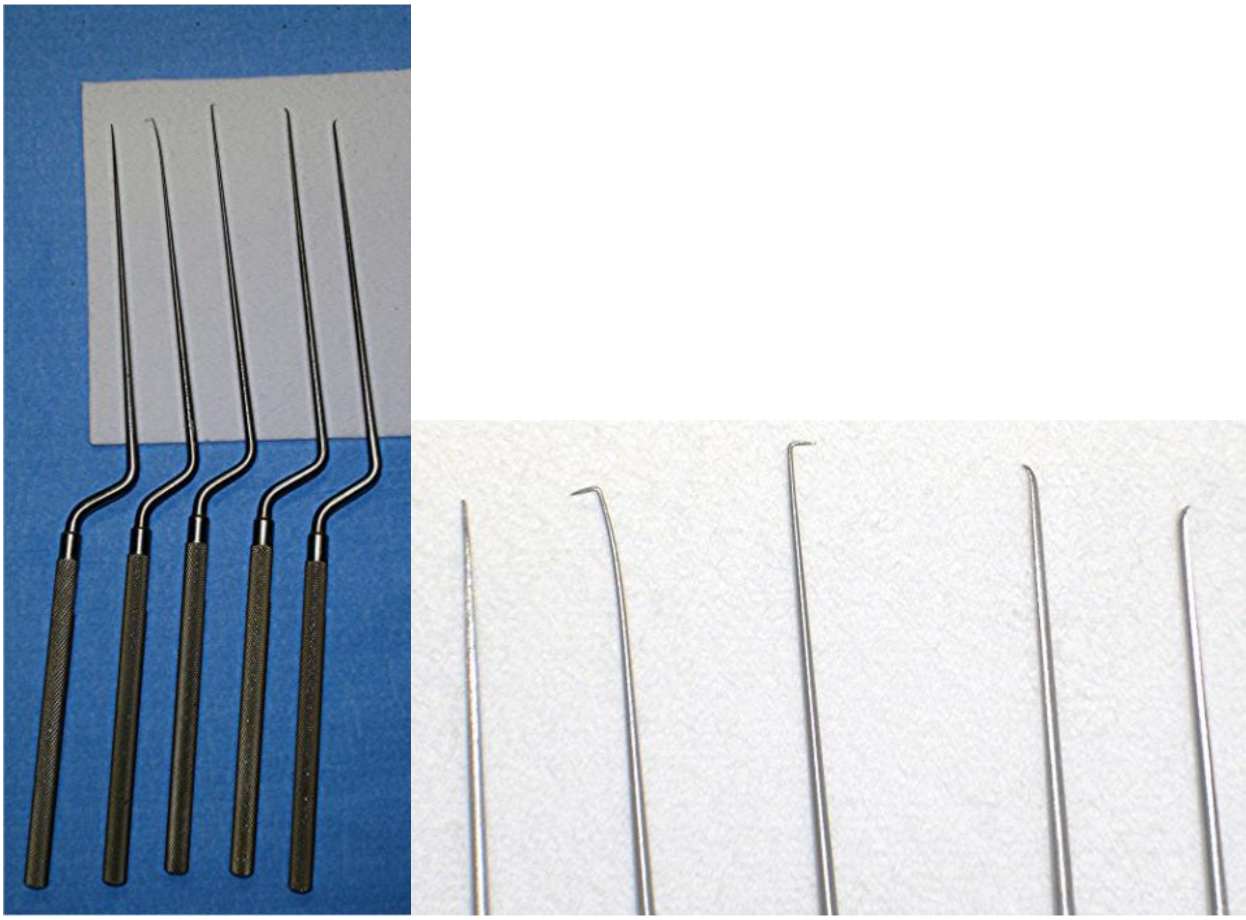
-Straight instruments:

- ✓ a hook.
- ✓ a blunt hook.
- ✓ two Marquet periostal elevator (1 left, 1 right).

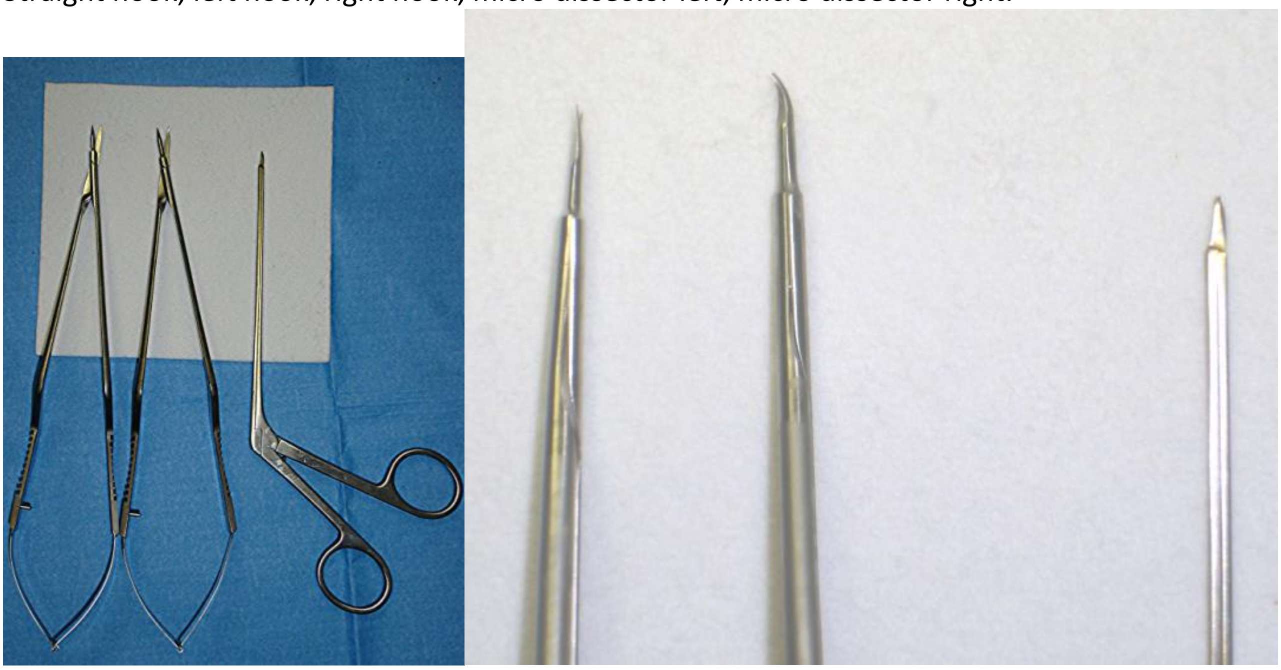
- Bayonet instruments

- ✓ One pointed and sharp
- ✓ Four small periostal elevator (facing up, down, left, right)
- ✓ four large periostal elevator (facing up, down, left, right)
- ✓ four hooks (facing up, down, left, right)

Instruments for otoneurosurgery approach :
Scalpel n°23
Dissection griffes
Wulstein auto-static
Rugine de Lampert
Bipolair forceps
Scalpel for dura
Scalpel n°11
Dissection griff De Bakey
Scissor Allaine
Needle holder



Micro- instruments for otoneurology from left to right:
Straight hook, left hook, right hook, micro dissector left, micro dissector right.



Micro-scissors: from left to right : scissors of Yasargil straight and curve, Sterkers scissor.

Consumable Material

- Two suction tubes, with suction cannulas of different sizes.
- Operating light handpiece.
- Microscope case, camera cover, instrument pocket.
- Xomed / Medtronic® 2-channel electrode set for monitoring the facial nerve.
- Scalpel blades: 22, 11.
- Glass scalpel blades.
- Surgical gloves and caps
- Adhesive surgical (craniotomy pack).
- Sterile woven and nonwoven compresses.
- Syringe and needle infiltration.
- Drugs: 0.5% adrenaline xylocaine, saline, sterile water
- Neuropatch (Braun®)
- Fibrillar Surgicel
- Biological glue (Tissucol®) 2ml
- Horsley Wax
- Cottons of neurosurgery (Codman®) cut into various sizes that will be carefully counted (opposite)
- Teflon (Bard®PTFE) cut into various sizes then crushed to be thinned
- Lyophilized hardstock or Durapatch Ethisorb Polyglactin910 / Polydioxanon (Ethicon®)


Teflon (Bard®PTFE) cut into various sizes then crushed to be thinned


Lyophilized hardstock or Durapatch Ethisorb Polyglactin 910 / Polydioxanon (Ethicon®)

Da: Fernanda - ABORLCCF <revista@aborlccf.org.br>
Inviato: lunedì 17 settembre 2018 18:32
A: 'Arianna Di Stadio'
Oggetto: RES: URGENT: ENDOSCOPE-ASSISTED RETROSIGMOID APPROACH IN HEMIFACIAL SPASM : our experience. Need to use images

Dear Author,

We authorize, provided they cite the bibliography reference when using the images.

Best regards,
Fernanda Vieira
Depto. Publicações
revista@aborlccf.org.br