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Microsurgical anatomy of the retroauricular, transcervico mastoid infralabyrinthine approach to jugular foramen

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ABSTRACT

This article presents the microsurgical anatomy of jugular foramen through the retroauricular, transmastoid infralabyrinthine approach. This method is easier than the classical infratemporal approach and provides better exposure for the cranial nerves reaching the neck. Detailed steps of infralabyrinthine, transcervico-mastoid approach are demonstrated using cadaveric dissection, along with description of relevant microsurgical anatomy of this region. This is a less complex and lesser time-consuming approach to the jugular foramen region, which can be combined with several other exposures depending on the extension of tumour.

Key words: microsurgical anatomy, jugular foramen approach, retroauricular infralabyrinthine, facial nerve course, high cervical exposure

Introduction

Lesions originating from the neurovascular structures in the jugular foramen constitute one of the major challenges of skull base surgery. Jugular foramen is indeed the most complex of the foramina through which the cranial nerves pass, although the subject of many studies, remains poorly understood. Surgery is accepted as the primary modality of treatment of the lesions arising in this region [1]. It is traditionally a region of interest for neuro-otologists and neurosurgeons. With the application of skull base approaches, tumors in this area can be removed, surpassing the difficulties posed by deep location and surrounding critical structures [2, 3].

Schwannomas, glomus jugulare tumors, meningiomas, chordomas, chondrosarcomas etc are the commonest tumors in this area. These tumors are basically not malignant, but slow growing tumors which may take four months to ten years to develop symptoms in various parts of the body [1].

The tumors of this region extend in growth via three important directions: (a) intracranial extension (b) temporal bone and pyramis extension and (c) high cervical region extension. It is highly essential to deal with the microanatomy of the high cervical region and temporal region, especially when they are not covered in cranial neurosurgery books quite often. The aim of the present discussion is to display the anatomical relationships of the cranial nerves and great vessels encountered in this approach.

Methods

The steps of cadaveric dissection are mentioned below:

The cadaveric head is stabilized using with three-point fixation, rotated contralaterally, so that the sagittal suture is nearly parallel to the floor (Fig. 1a).

A curvilinear skin incision starts from about 7 cm above the level of external acoustic meatus, passing over the temporal region, to reach 4-5 cm behind the mastoid tip and further down along the border of the sternomastoid muscle to the level of the angle of mandible. The skin flap is then retracted and muscles over the mastoid bone are divided.

High cervical exposure is then carried out as detailed. Blunt dissection is employed to identify the posterior angle of mandible as well as the anterior border of sternomastoid and the great auricular nerve (Fig. 1b). The anterior and mid-insertion points of the sternomastoid muscle to the mastoid tip are detached by means of blunt dissection, leaving the posterior insertion of the muscle

to the bone intact. The great auricular nerve is sacrificed, while maintaining a long stump for those in whom a nerve graft may be needed. The posterior border of the angle of mandible and the superficial posterior border of the mastoid tip define the anterior as well as posterior limits of this approach respectively.

The anterior belly of the sternomastoid muscle is then retracted posteriorly to achieve adequate exposure of the posterior belly of digastric muscle. The loose connective tissue sheath of the posterior belly of digastric is carefully removed to facilitate mobilization of muscle as described later in the text. The posterior belly of digastric is retracted antero-superiorly, to expose, identify and avoid injury to the accessory nerve that runs in the postero-inferior direction, between the posterior belly of digastric above and internal jugular vein below. An important landmark for identification of accessory nerve along the internal jugular vein, at a point approximately 3-15 mm inferolaterally to the anterior edge of the transverse process of atlas, which is in turn exposed after dissection of the suboccipital triangle.

After identification of the accessory nerve, the infero-posterior retraction of the posterior belly of digastric muscle is applied in order to identify the occipital

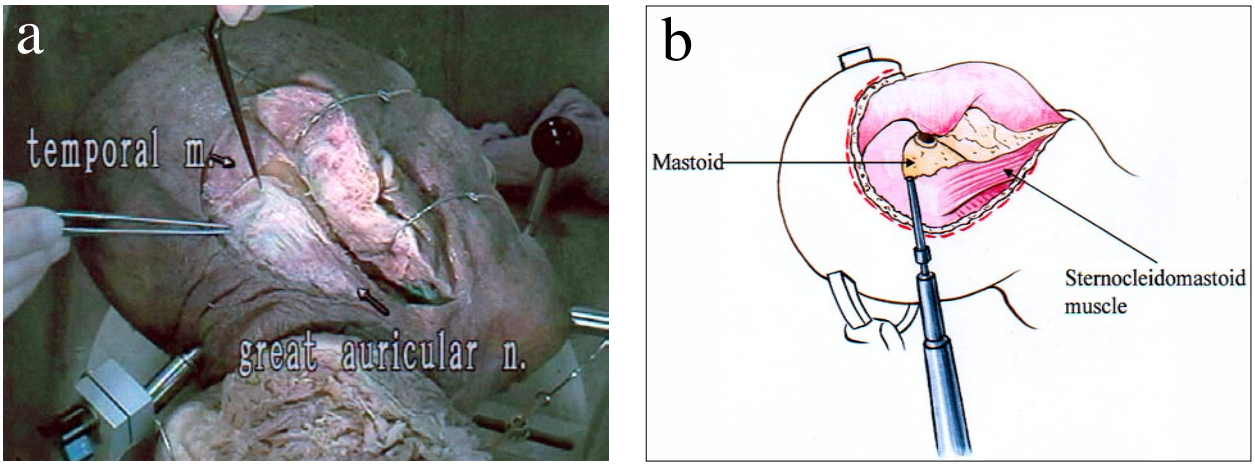

Figure 1 | Figure (a, b) illustrates the head position on three point fixation frame and skin flap incision showing exposure of the mastoid bone along with great auricular nerve.

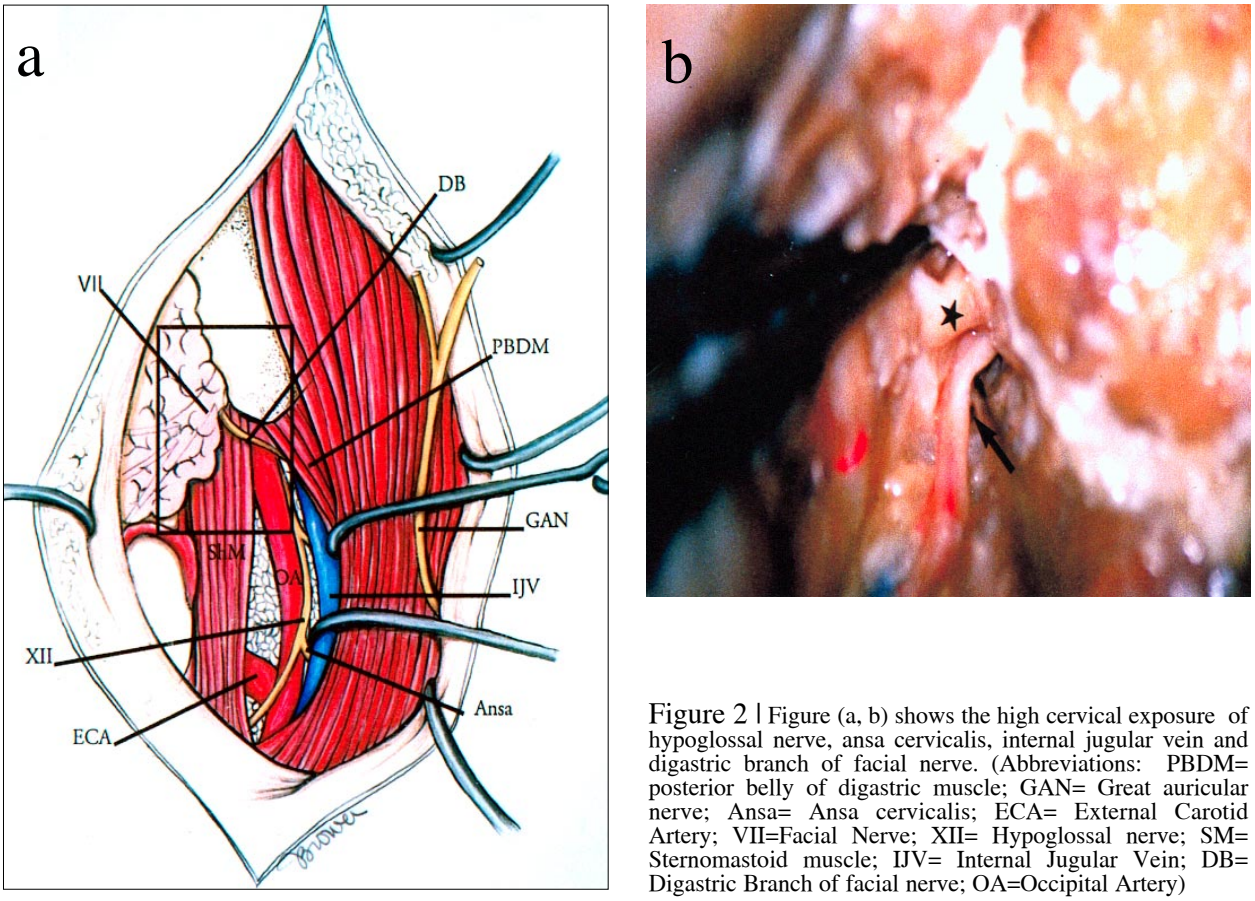

Figure 2 | Figure (a, b) shows the high cervical exposure of hypoglossal nerve, ansa cervicalis, internal jugular vein and digastric branch of facial nerve. (Abbreviations: PBDM= posterior belly of digastric muscle; GAN= Great auricular nerve; Ansa= Ansa cervicalis; ECA= External Carotid Artery; VII=Facial Nerve; XII= Hypoglossal nerve; SM= Sternomastoid muscle; IJV= Internal Jugular Vein; DB= Digastric Branch of facial nerve; OA=Occipital Artery)

artery and the hypoglossal nerve, which runs parallel and inferior to the occipital artery. Inferiorly, using blunt dissection, the superior root of the ansa cervicalis is exposed, proceeding to the point where the ansa cervicalis leaves the hypoglossal nerve, running parallel in the posterior part of the internal carotid artery. Next step is the exposure of the digastric branch of seventh nerve. Continuing anteriorly with blunt dissection, a posterior partial parotidectomy for approximately 2 cm is performed, exposing the main extracranial trunk of the facial nerve (Figs. 2a, b).

Exposure of the styloid process is the next vital step, (Figs. 3a, b); styloid process is reached by dissecting along the superior aspect of the course of seventh nerve identified. The following three muscles are identified, attached to the styloid process - stylohyoid to the posterior aspect, styloglossus to the tip and stylopharyngeus to the medial aspect of the base of the styloid process. Without detaching their attachements, the styloid process is then fractured and retracted downwards at its point of insertion to the base of skull. This bone removal facilitates partial exposure of the high cervical carotid artery segment, at

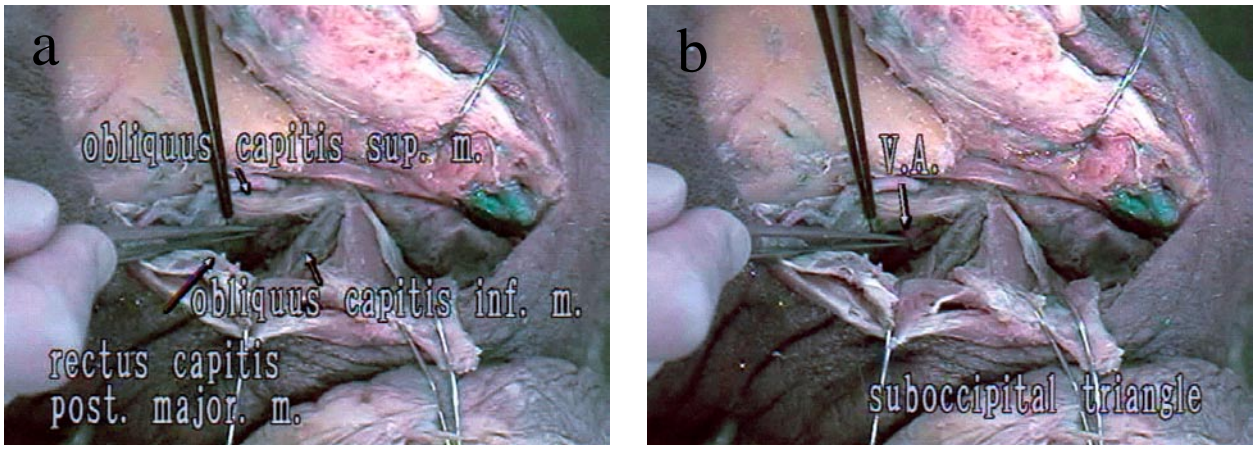

Figure 3 | Figure (a, b) shows the dissection of the suboccipital triangle exposing the anterior edge of transverse process of atlas, of localizing value for vertebral artey and accessory nerve.

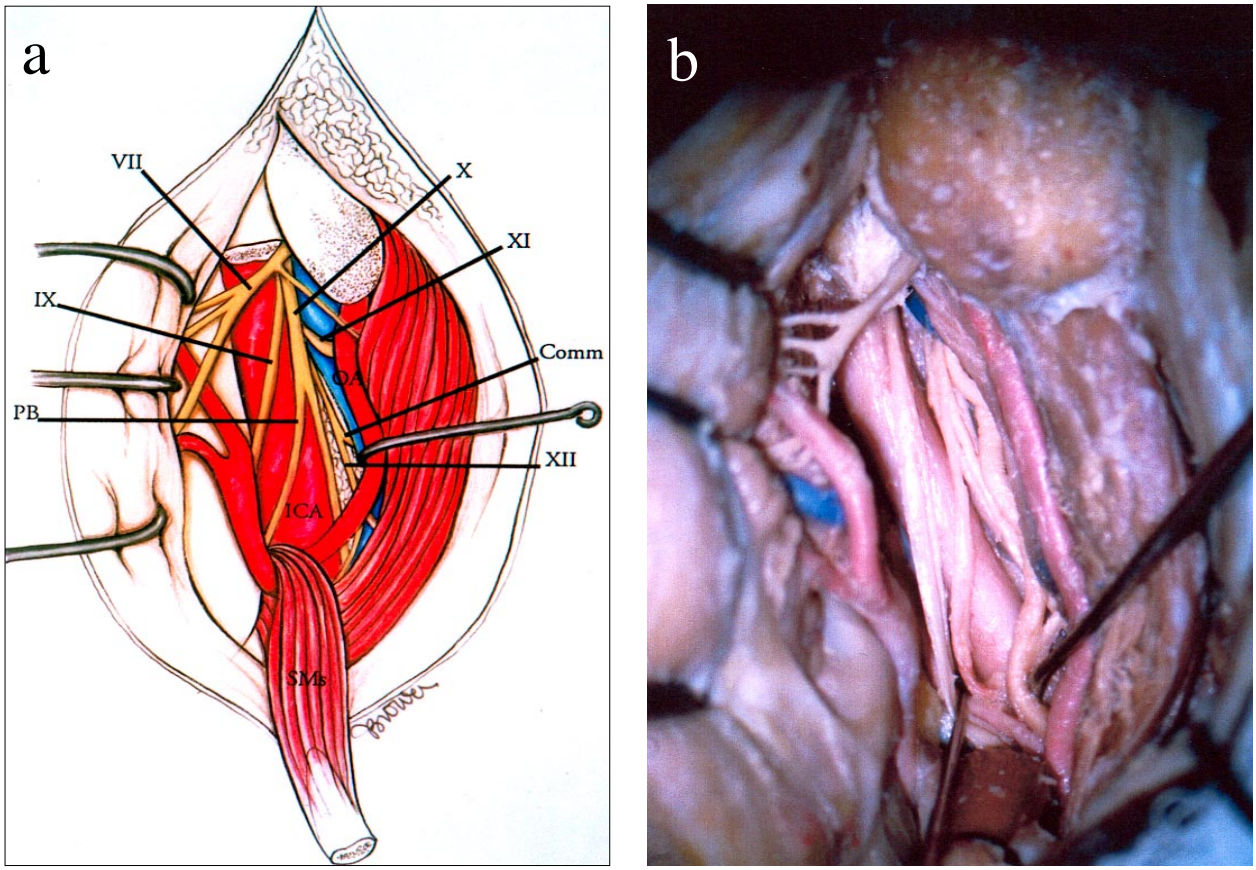

Figure 4 | Figure (a, b) showing high cervical exposure of cranial nerves VII, IX, X, XI and XII, after retracting the styloid process with attached muscles. (Abbreviations: VII=Facial Nerve, IX=Ninth Nerve; X=Tenth nerve; XI=Accessory Nerve; Comm= Communicating branch of hypoglossal nerve to C1 nerve)

the entry point into the carotid canal (Figs. 4a, b). This site where internal carotid artery becomes intracranial is also the point where internal jugular vein drains from the cranial cavity [4].

Approximately 1-2 cm inferior to this entry point of carotid artery, two important lower cranial nerves are identified- 9th (glossopharyngeal nerve) seen on posterior aspect superiorly and 10th (vagus neve) inferiorly, crossing the carotid artery in a latero-medial direction, cephalocaudally. The retraction of the internal jugular vein posteriorly helps to expose the carotid branch of the glossopharyngeal nerve, also termed the carotid sinus nerve. The hypoglossal nerve, ansa cervicalis and the communicating branch with ventral ramus of C1 nerve are noted along with the origin of superior laryngeal nerve at the level [5] (Figs. 5a, b).

The mastoidectomy is undertaken now. The spine of Henle is the landmark to the lateral genu of the facial nerve (Figs. 6a, b). The mastoid bone is decorticated by drilling the bone posterior to the external auditory

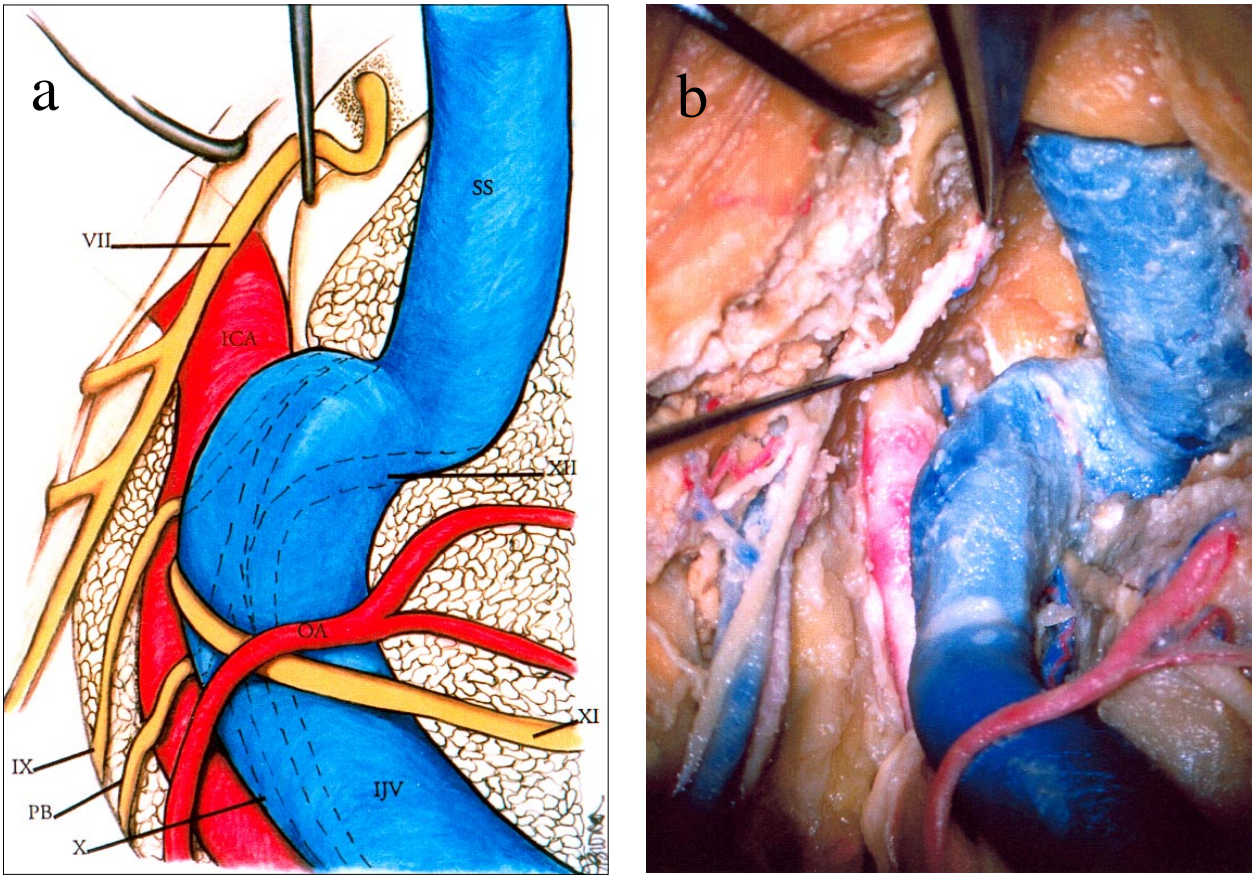

Figure 5 | Figure (a, b) illustrates the internal carotid artery, sigmoid sinus, origin of internal jugular vein, along with cranial nerves VII, IX, X, XI, XII after removal of jugular process of occipital bone and the posterolateral lip of jugular foramen. (Abbreviations: OA= Occipital Artery, ICA=Internal Carotid Artery; IJV=Internal Jugular Vein)

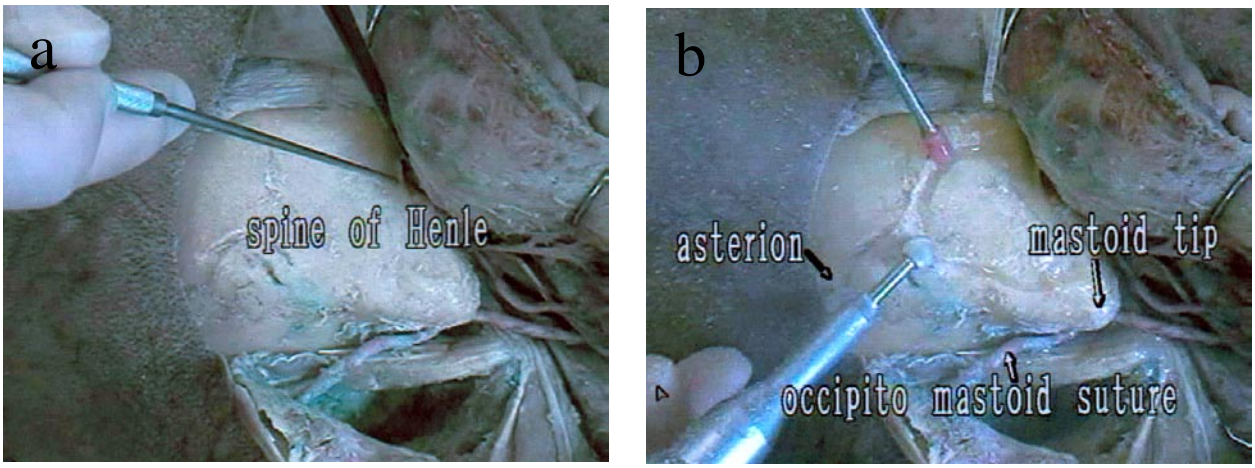

Figure 6 | This figure (a, b) illustrates the extent and landmarks in performing mastoidectomy to unroof the sigmoid sinus and vertical segment of facial nerve.

canal and the underlying sigmoid sinus (Figs. 7a, b). The mastoid air cells are removed and the middle cranial fossa and meatal bone plates are dissected until the antrum is identified. The cortical bone of the lateral semicircular canal can be identified through the antrum. The posterior semicircular canal is located by exposing the endolymphatic sac, which also serves as an important landmark during this exposure [6].

Then, the bone over sino-dural angle is removed and the sigmoid sinus is completely exposed. With further drilling of the mastoid air cells, the digastric ridge is exposed, which is a landmark for stylomastoid foramen and the beginning of the fallopian canal. This is the most important landmark in facial nerve identification, during surgery. Removal of the sigmoid plate, the bone of sinodural angle exposes the superior petrosal sinus also. The superior semicircular canal can be exposed by following the posterior semicircular canal superiorly (Figs. 7c, d). Further removal of the mastoid air cells completely exposes the fallopian canal which runs from the digastric ridge to the lateral semicircular canal (Figs. 8a, b).

After mastoidectomy, the venous system must be identified. The important veins in this region are: 1. transverse sinus 2. sigmoid sinus 3. superior petrosal vein 4. jugular bulb 5. anterior condylar vein 6. condylar emissary vein 7. inferior petrosal sinus and 8. internal jugular vein. Inferior petrosal sinus joins the jugular bulb -in 30% of cases- [7], commonly between 9th and 10th cranial nerves. Sigmoid sinus has a vertical segment and a short horizontal limb and drained into the superior aspect of the jugular bulb. Within the jugular foramen, the superior jugular bulb lies posterolateral to the 9th,10th and 11th cranial nerves. The dome of superior jugular bulb is located in the jugular fossa, which may vary from rounded to conical shapes [8].

It is to be noted that the greater superficial petrosal nerve (GSPN) is already given off, before the seventh nerve enters the fallopian canal (Fig. 8c). After emerging out of the stylomastoid foramen, the facial nerve is found entering the parotid gland as detailed earlier in the text. Chorda tympani nerve can also be exposed by this approach, but not required usually in tumor resections.

The exposure of the internal carotid artery is crucial in this approach. The cochlea and the infralabyrinthine bone are drilled further to expose the vertical segment of the internal carotid artery [9]. When more exposure of carotid artery is required, combination approaches like labyrinthectomy and facial nerve transpositioning [10] can be tried.

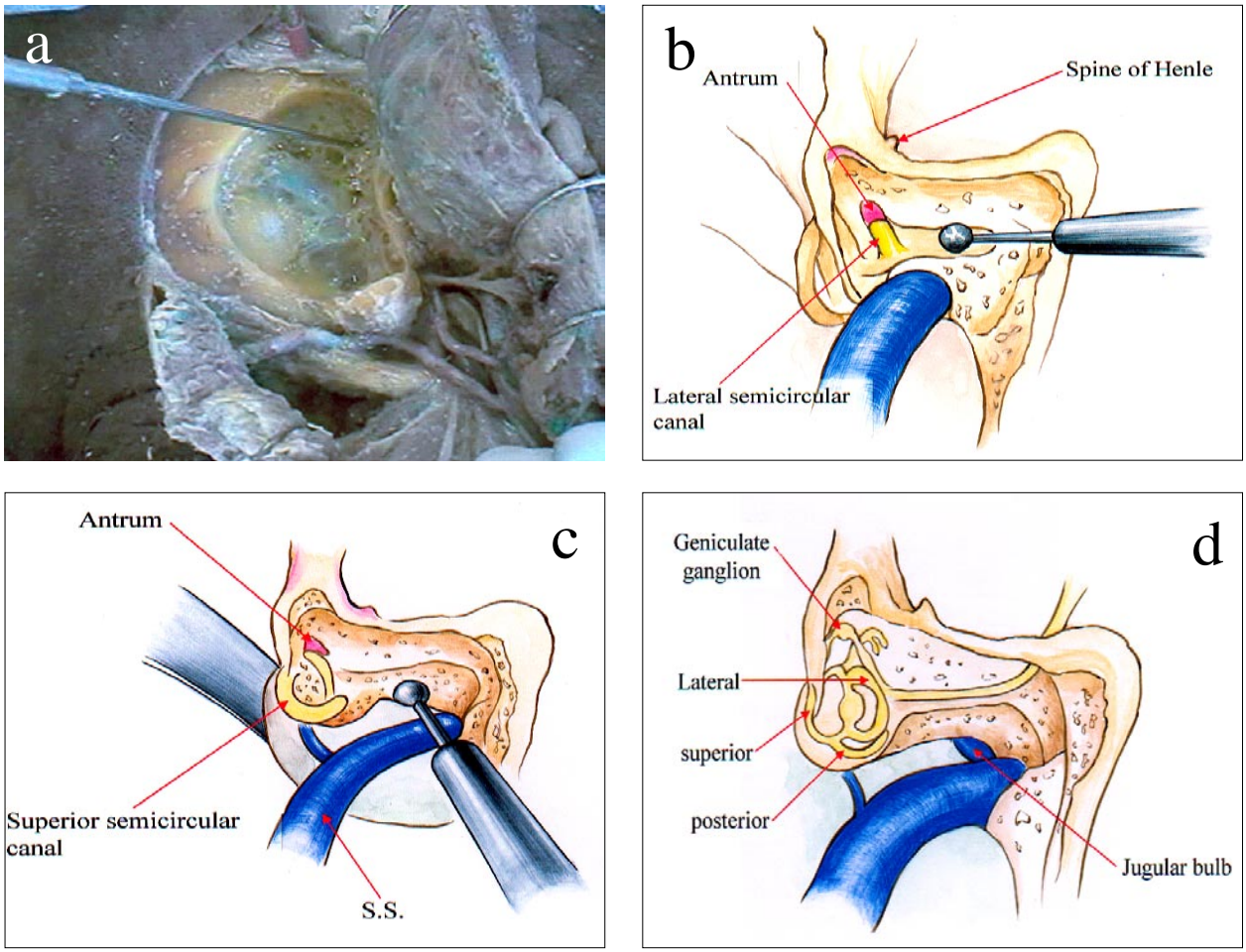

Figure 7 | The diagram (a, b) depicts the surgical anatomy of mastoid bone after exposing the antrum and lateral semicircular canal. The diagram (c, d) illustrates all the semicircular canals, geniculate ganglion and the junction of jugular bulb with sigmoid sinus.

Discussion

Jugular foramen is located at the skull base, in the posterior aspect of the petro-occipital fissure, bounded anterolaterally by the petrous bone and posteromedially by the basi-occipital bone [8]. Knowledge of anatomy of jugular foramen is crucial in performing tumour resections in this region. The understanding of bony anatomy in preoperative radiological evaluation [2] and the microsurgical anatomy of cranial nerves and vascular architecture (both arterial and venous) are the key factors in successful tumorectomy [2, 3]. Venous bleeding is a dreaded complication during operations in this region. Within the jugular foramen, pars venosa located posterolaterally is separated from the nervosa by either bone, fibrous tissue or thin connective tissue. Pars venosa contains the jugular bulb along with X and XI nerves. Pars nervosa contains the inferior petrosal sinus, glossopharyngeal nerve and vena canaliculi cochlea

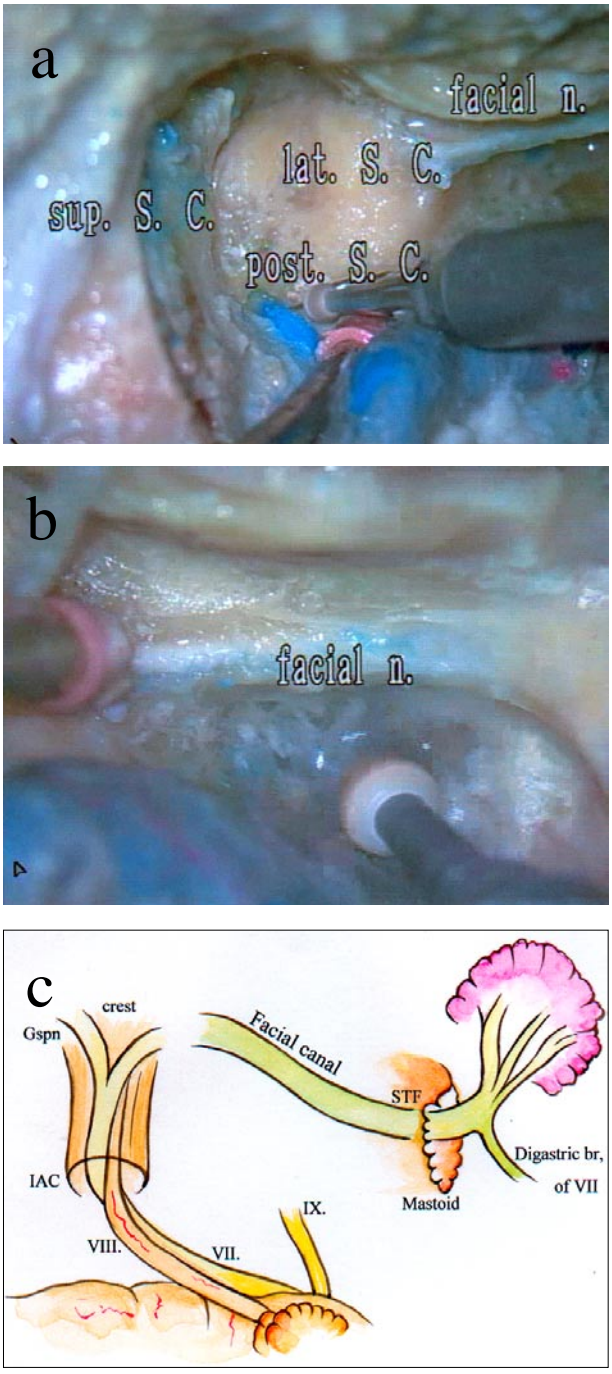

Figure 8 | Figure (a, b) illustrates the entire course of facial nerve between the lateral semicircular canal and the digastric ridge, in the cadaver photograph. Figure (c) shows the diagrammatic representation of the course of facial nerve in this approach.

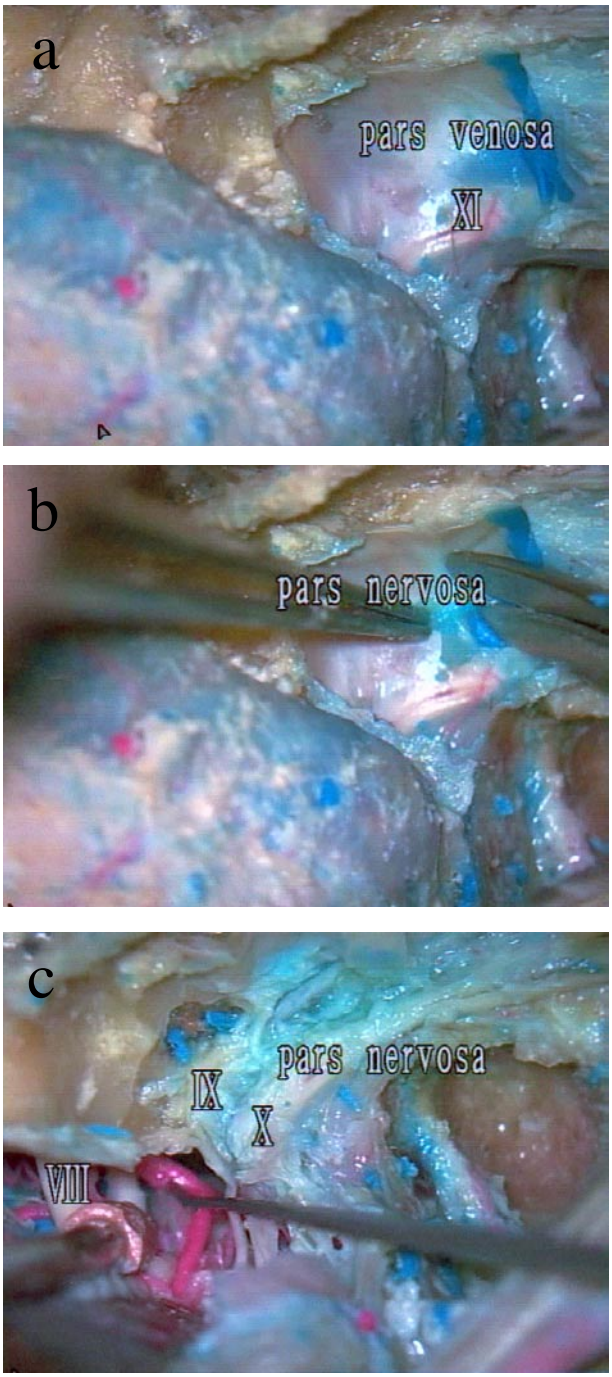

Figure 9 | Figure (a, b, c) shows the pars venosa and nervosa subdivisions of jugular foramen with its contents.

(Figs. 9a, b, c). The venous system of this region, as mentioned before is highly complex in organization. Katsuta et al. [11] has classified them into two major systems - a larger posterolateral venous channel, called the sigmoid part, receiving the flow of sigmoid sinus and a smaller anteromedial venous channel called the petrosal part, which receives the drainage of the inferior petrosal sinus. Packing of these sinuses during surgery is therefore a crucial step in satisfactory hemostasis as well as cranial nerve preservation.

During surgery, the jugular bulb is opened after ligation of the sigmoid sinus using Titanium clips, between the superior petrosal sinus above and internal jugular vein below. Incision is made across the sigmoid sinus to the presigmoid posterior fossa dura. At this point, the tumor invading the jugular bulb is removed. Then the inferior petrosal sinus openings are identified and packed with Biobond and surgicel. The orifices should not be overpacked as it may injure the glossopharyngeal nerve in pars nervosa region of the jugular foramen. After packing inferior petrosal sinus orifices, the dura over the pars nervosa is opened. A bone punch may be used to remove the osseous bridge which may be seen separating the pars venosa from nervosa. This approach helps to trace the cranial nerves at the junction between their intracranial and high cervical extracranial regions, reliably and safely [10]. It is to be emphasized that there is no universal agreement regarding the position of cranial nerves in the jugular foramen [12].

The major technical complications that can occur intraoperatively are: 1) damage to the lower cranial nerves while dissecting the contents of jugular foramen, 2) troublesome venous plexus bleeding which fills the surgical field, 3) excessive packing of inferior petrosal sinus opening, which compresses the nerve.

The relatively rarer complications are: 1) cerebrospinal fluid leak 2) hearing impairment which was absent preoperatively and 3) respiratory embarrassment requiring a tracheostomy.

These operative morbidities and the relatively well-preserved preoperative neurological status have led to a major controversy as to whether these aggressive surgeries are truly necessary. However, this approach is better than the pre-auricular subtemporal - infratemporal and the far lateral approaches to jugular foramen, as it exposes the entire distribution of cranial nerves in this region. The major advantages of this approach are:

1. There is no ablation of ear srtructures except the infralabyrinthiine portion of mastoid bone.
2. The auricle is retracted anteriorly while preserving the bony wall and skin of the ear canal.
3. Facial nerve is rerouted only for a limited segment
4. Extended intracranial masses can be resected by combination procedures as each case demands.
5. Less cumbersome and time –consuming than other procedures.

Conclusion

It is important for a neurosurgeon to understand the microsurgical anatomy of the jugular foramen region, which is one of the complex areas of skull base. Though the tumors here are rare and slow growing, surgical treatment is well accepted modality in its management in view of its characteristic patterns of invasion and destruction of adjacent tissue planes. This approach allows wide exposure of the lower cranial nerves entering the neck, allowing their planned preservation, thereby reducing the postoperative morbidity. This is the method of choice in patients with remnant hearing [10] and when there is cervical extension of the mass.

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