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Technical Notes & Surgical Techniques

Infratemporal approach with anterior transposition of facial nerve in paraganglioma surgery

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ABSTRACT

Introduction: The treatment of glomus jugulare tumors can be extremely challenging. In certain patients, residual tumor is left at surgery to prevent devastating lower cranial nerve deficits or to reduce potential morbidity associated with carotid artery injury. The interest of this article is to demonstrate the importance of anterior transposition of the facial nerve in the approach of the jugular paraganglioma and to analyze the surgical technique, complications, and outcomes.
Methods: We retrospectively studied 07 patients with jugular paragangliomas treated between January 2010 and December 2016 at Ali Ait Idir University Hospital in Algiers, Algeria. All patients were operated by the infratemporal fossa approaches type A (Fisch) [13]. We have developed for better exposed jugular golf the anterior transposition of the facial nerve. Preoperative embolization was performed for all patients.
Results: Total removal was possible in 04 patients. The most frequent and also the most dangerous surgical complication was lower cranial nerve deficit. This deficit occurred in 02 patients, but it was transient in one cases. Cerebrospinal fluid leakage remains a potentially fatal complication. In our study two patients developed CSF leaks and were treated conservatively with iterative lumbar punctures. Transposition of a normal facial nerve usually causes moderate postoperative paresis that may improve partially within 3 to 6 months.
Conclusion: Radical resection of jugular paragangliomas is difficult, and infratemporale approach (Fisch type A) with anterior transposition of facial nerve offer the best chance of total removal with preservation of facial and lower cranial nerves.

1. Introduction

In 1941, Guild [1] described carotid body–like structures in the temporal bone and named them “glomus jugulare bodies.”

In 1945, Rosenwasser [2] published the first description of a middle ear paraganglioma and associated these tumors with the glomus jugulare bodies.

In 1962, Alford and Guilford [3] classified these lesions as glomus tympanicum and glomus jugulare tumors. Multiple terms have been used to describe paragangliomas—glomus tumor, chemodectoma, glomerocytoma, nonchromaffin tumor, tympanic body tumor, and receptoma are the most common [19].

Glomus jugulare tumors are rare tumors that are highly vascular, and arise from the chief cells of the paraganglia in the adventitia of the dome of the jugular bulb. The arterial blood supply comes from the ascending pharyngeal artery through its inferior tympanic branch [4].

Resection of these lesions is difficult for the following reasons: jugular foramen tumors are deeply located, highly vascularized and may involve or infiltrate cranial nerves, vessels, brainstem, and the bone structures at the cranial base.

The multidisciplinary approach gives the best chance of radical removal with preservation of cranial nerves, vessels, and the brainstem.

Since the early 2008s, we have attempted to develop a multidisciplinary surgical approach to the jugular foramen. In this article, we will present the preoperative considerations; the surgical techniques used, the results, including complications and our outlook.

1.1. Materials and methods

From 2008 to 2016 we treated 07 tympanojugular paragangliomas. There were 01 man and 06 women. The average age of patients was 40 years (extreme ages were 32 and 62 years old). The most common symptoms were hearing loss and pulsating tinnitus. Duration of symptoms ranged from 8 months to 3 years.

Preoperative high-definition CT scans (Fig. 1) were obtained for analysis of bone structures of the cranial base, tumor calcification, hyperostosis, and bone erosion. Preoperative MR imaging (Fig. 2) with addition MR angiography was performed to study tumor vascularization, extension, and its relationship to neighboring structures. Venous circulation and occlusion of the sigmoid sinus were studied with MR

Abbreviations: ICA, internal carotide artery; CSF, cerebrospinal fluid; PG, parotid gland; VII, Facial nerve; MT, mastoid tip; IJV, internal jugular vein; U, uncus; LSC, lateral semicircular canal

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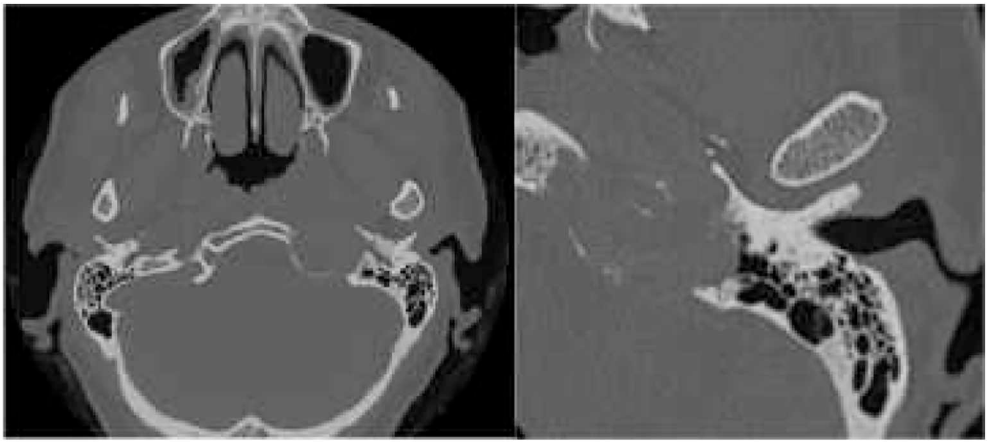

Fig. 1. CT of the temporal bone: Tympano-jugular paragangliomas produce a characteristic "moth-eaten" pattern of bone destruction.

angiography (Fig. 3). Digital subtraction angiography (Fig. 4) was performed for diagnosis and to guide preoperative embolization.

Embolization was performed 3 to 5 days before the surgical procedure. Tumor feeding vessels (ascending pharyngeal, internal maxillary, and occipital arteries, carotid tympanic branches, and the posterior inferior cerebellar artery) were embolized (Fig. 4).

Temporal bone paragangliomas are classified according to Fisch and Mattox classification (Table 1) [5–18]. All our patients were classified in the C1 stage of Fisch (Table 2): the tumor arise in the dome of the jugular bulb and destroy the overlying cortical bone. It erodes carotid foramen but does not invade the carotid artery.

2. Surgical technique

The infratemporal appoach type A consists of the following steps:

– Facial Nerve Management
– Vascular control in the Neck
– Closure of external auditory canal
– Temporal bone dissection
– Facial nerve rerouting
– Opening of the jugular foramen
– Tumor Removal
– Wound closure

2.1. Patient position

The patient is placed in the dorsal position with the head turned 45° to the opposite side. The opposite jugular vein must be free from compression. An intraoperative monitoring of facial is performed.

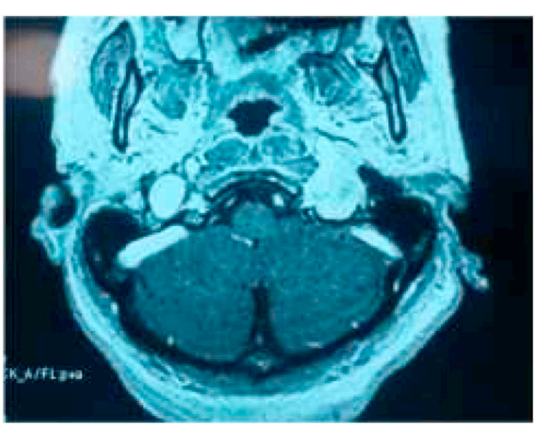

Fig. 2. MRI, the "salt and pepper" appearance is typical: The "pepper" component represents the multiple areas of signal void, interspersed with the "salt" component, which is seen as hyperintense.

2.2. Incision (Fig. 5)

The skin incision is C-shaped and is placed 4 cm behind the postauricular crease. The superior limb extends to the frontotemporal hairline and extends inferiorly to the neck following the anterior border of the sternomastoid muscle up to the level of the thyroid cartilage.

2.3. Facial nerve management

The facial nerve exits the stylomastoid foramen superiorly to the digastric muscle. The extra cranial portion of Facial nerve is identified distal to the stylomastoid foramen using the following parameters: the mastoid tip, the posterior belly of the digastric muscle, and the tympanomastoid suture (Fig. 6) [7,11].

The main trunk is skeletonized from the superficial lobe of the parotid gland until the temporal and zygomatic branches are exposed. Incomplete dissection from the parotid gland may tether the nerve and cause a stretch injury during anterior transposition as described below.

2.4. Vascular control in the neck

The sternocleidomastoid is freed from its insertion to the mastoid tip and reflected posteriorly.

The digastric muscle is removed from its groove and reflected anteriorly. This allows the identification of the internal jugular vein and the internal carotid arteries in the neck (Fig. 7).

2.5. Closure of external auditory canal

The ear is dissected anteriorly, and the ear canal is transected at the cartilage-bone junction.

The cuff of canal skin is dissected from the cartilage surrounding the meatus and everted. This everted skin is closed with interrupted sutures (Fig. 8).

2.6. Temporal bone dissection

The important bony landmarks that are identified at this point are:

– anteriorly the spine of Henley and the posterior rim of external auditory canal,
– posteriorly the backside of the body of the mastoid (this is the ridge at the posterior margin of the mastoid bone),
– superiorly the temporalis linea, and

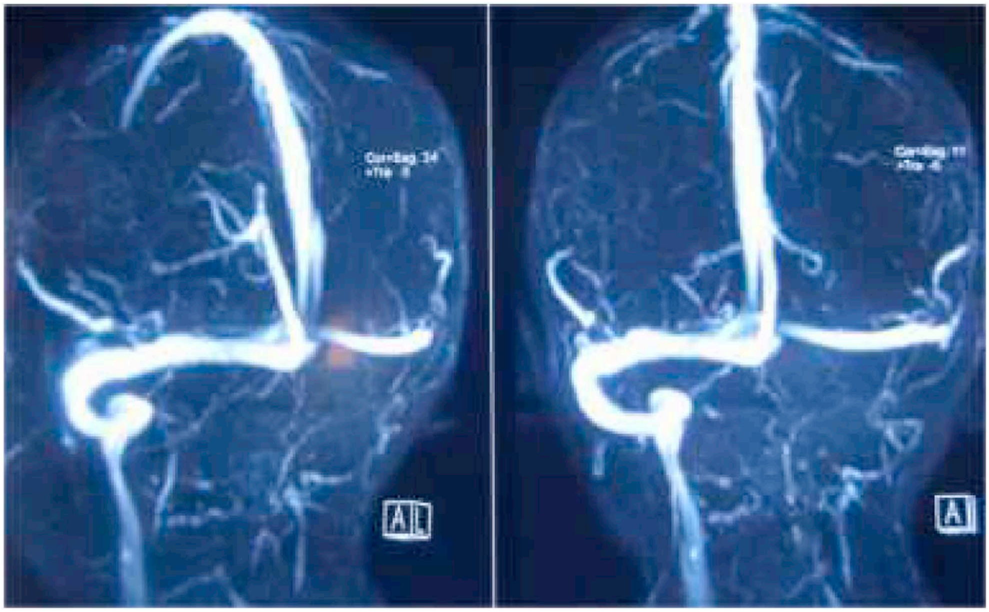

Fig. 3. Magnetic resonance angiography (MRA) is helpful in determining the patency of the contralateral sigmoid sinus and internal jugular vein.

– Inferiorly the mastoid tip.

The spine of Henley or suprameatal spine, is a small bony prominence that is located at the postero-superior rim of the external auditory canal and is useful as a superficial landmark that approximates the deep site of the lateral semicircular canal and the tympanic segment of the facial nerve [20].

Bone removal is started along the posterior rim of external auditory canal to the mastoid tip, and then horizontally along the temporalis linea. The junction of these lines lies over the mastoid antrum.

Posteriorly the sigmoid sinus is uncovered, generally appears as a blue discoloration of smooth dural bony plate. Bleeding from the sigmoid sinus can be controlled with surgicel and bipolar coagulation. As soon as the sigmoid sinus has been outlined, the operating microscope is brought into place. Removal of bone over the sigmoid sinus must be done carefully.

Once skeletonizing of the sigmoid sinus is completed, mastoid air cells are removed anteriorly and superiorly to expose the middle fossa dura. Once the heavy bone is removed, thinning can be performed with a diamond tip, which results in less bleeding and less risk of lacerating the dura. Exposing the middle dura is critical for best possible access into the antrum.

The area between the sigmoid sinus and the middle fossa plate, or the sinodural angle, can be fully evacuated of air cells. Firstly the sinodural angle is delineated by using a medium-sized cutting burr, then a diamond burr. The superior petrosal sinus, which runs along the sinodural angle inside the dura, should always be kept in mind and the drilling executed with care [20].

The external opening must be as large as possible and a wide cortical mastoidectomy is performed with exceeding of the edges at least 2 cm posterior to the sigmoid sinus.

Subsequently, the air cells surrounding the inferior segment of the sigmoid sinus and the digastric ridge are removed. The digastric ridge constitutes an important landmark in locating the facial nerve at the stylomastoid foramen. The ridge is formed by the impression of the digastric groove, which houses the origin of the posterior belly of the digastric muscle. This ridge leads directly to the stylomastoid foramen [16,20].

The next step is opening the mastoid antrum in the superior portion of the exposure. The antrum can be identified as a larger aircontaining space, lies immediately below the deepest point of penetration into the temporal bone posterior to the spine of Henley and the temporalis linea. The horizontal semicircular canal is plainly seen in the open antrum, oriented in the axial plane.

Exposure should be carried anteriorly until the entire length of the lateral semicircular canal is visible in the medial wall of the antrum, thus revealing the short process of the incus.

The superficial landmark for the incus is the spine of Henley

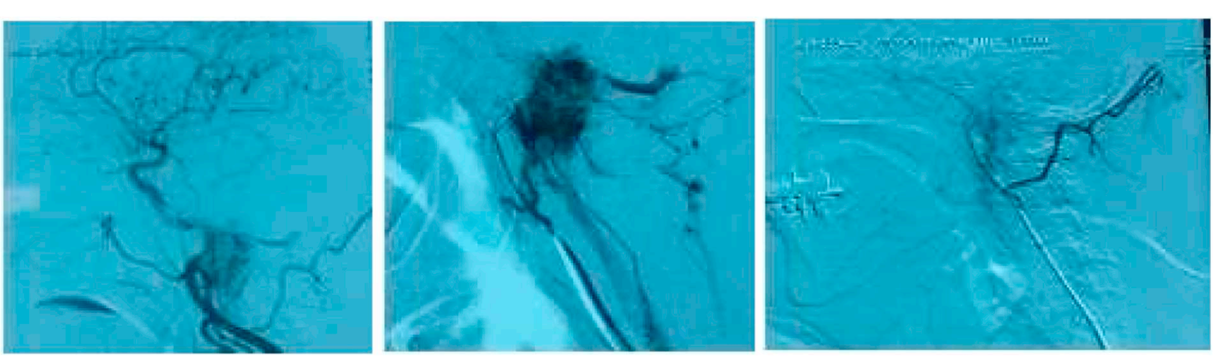

Fig. 4. Digital subtraction angiography was performed for diagnosis and to guide preoperative embolization. Tumor feeding vissels were embolized (occipital and auricular artery).

Table 1
Fisch and Mattox Classification of glomus temporale tumors.

Class A Tumors arise along the tympanic plexus on the promontory of the middle ear. Blood supply is from the tympanic artery, a branch of the ascending pharyngeal artery.
Class B tumors originate in the canalis tympanicus of the hypotympanum and invade the middle ear and mastoid. The carotid foramen and canal are intact. These tumors invade bone, but the cortical bone over the jugular bulb is intact.
Class C Tumors arise in the dome of the jugular bulb and destroy the overlying cortical bone. They spread inferiorly along the jugular vein and lower cranial nerves, posteriorly into the sigmoid sinus, superiorly toward the otic capsule and IAM, laterally to the hypotympanum and middle ear, medially to the jugular foramen and CPA.
Subclassification is made according to the degree of erosion of the carotid canal:

- C1: erode carotid foramen but do not invade the carotid artery
- C2: destroy the vertical carotid canal between the carotid foramen and carotid bend
- C3: grow along the horizontal portion of the carotid artery but do not reach the foramen lacerum
- C4: grow to the foramen lacerum and along the carotid artery to the cavernous sinus.

Class D Tumors that have intracranial extension are further subclassified as follows:

- De: intracranial but extradural:
  De 1: displace posterior fossa dura < 2 cm
  De 2: displace posterior fossa dura > 2 cm
- Di: intracranial with intradural extension:
  Di 1: intradural extension < 2 cm
  Di 2: intradural extension > 2 cm
  Di 3: intradural extension that makes the tumor unresectable

IAM: internal auditory canal; CPA: cerebellopontine angle.

Table 2
Fisch classification of infratemporale fossa approaches.

Type A: approach provides exposure of the infralabyrinthine region and jugular foramen.

Type B: approach is designed for petrous apical and midclival tumors.

Type C: approach is an anterior extension of type B and provides access to the pterygopalatine fossa, parasellar region, and nasopharynx.

Type D: is a modification of the type B and C approaches and is best suited for resection of lesions of the mid and upper clivus, petrous apex, and cavernous sinus without violation of the middle ear or mastoid.

Fig. 5. The patient is positioned supine with an ipsilateral shoulder roll and the head turned 45° to the contralateral side. A postauricular C-shaped incision is made. The superior limb extends to the frontotemporal hairline and extends inferiorly to the neck following the anterior border of the sternomastoid muscle up to the level of the thyroid cartilage.

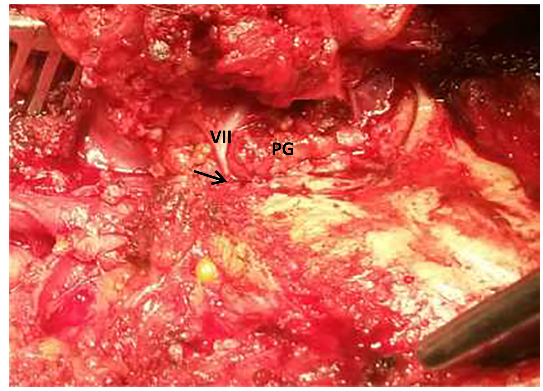

Fig. 6. The facial nerve (VII) is exposed distally as it enters the parotid gland (PG) from the stylomastoid foramen (black arrow).

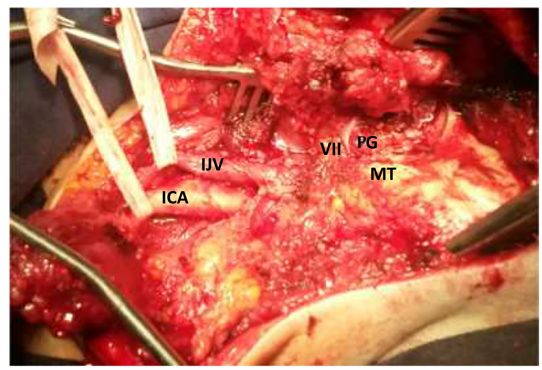

Fig. 7. The sternocleidomastoid muscle is mobilized posterioinferiorly, and the digastric muscle is detached from the mastoid tip (MT). The internal jugular vein (IJV) and the internal carotid arteries (ICA) in the neck are identified and controlled.

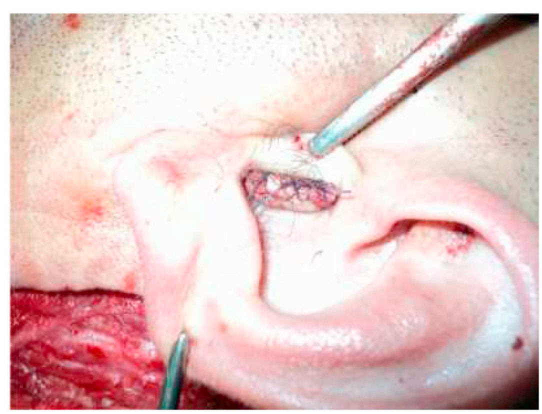

Fig. 8. Closure of external auditory canal.

[16,17]. By drilling deeper, to thin the posterior bony wall of the external canal at the level of the spine of Henley, the incus is exposed (Fig. 9).

The incus and lateral semicircular canal are used as landmarks to identify the descending facial nerve [17].

The remaining posterior bony of external auditory canal and skin are resected with a rongeur. The tympanic membrane, malleus, incus, and the remaining skin of the external auditory canal are sacrificed (Fig. 9). Care is taken because the internal carotid artery lies medial to the bony Eustachian tube.

The facial nerve is normally localized inferior and slightly medial to the horizontal semicircular canal. Dissection is accomplished with a

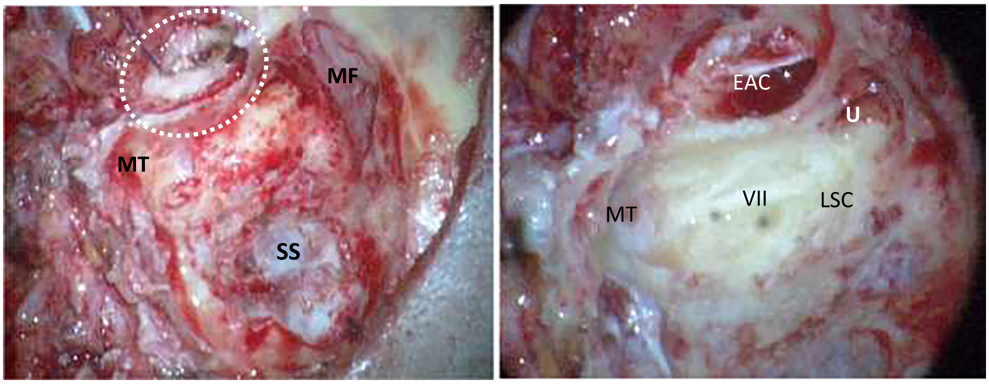

Fig. 9. The external auditory canal (white circle) is transected at the level of the bone-cartilage junction. The remaining posterior bony of external auditory canal and skin are resected with a rongeur. The incus (U) and lateral semicircular canal (LSC) are used as landmarks to identify the descending facial nerve (VII).
MF: middle fossa, MT: mastoid tip, SS: sigmoid sinus.

cutting burr until a change in bone character is identified. Once the facial nerve is identified, the nerve is skeletonized along its vertical portion from the geniculate ganglion to the stylomastoid foramen (Fig. 10).

This dissection is performed with a diamond burr, and profuse irrigation is used to prevent frictional heating of the nerve. A thin shell of bone is left on the facial nerve. Anteriorly the chorda tympani nerve is detected and it leaves the facial nerve at an acute angle toward the tympanic cavity.

Once the facial nerve is defined, the retrofacial air cells between the facial nerve and the jugular bulb are removed. Removal of these cells, until the blueness of the dome of the jugular bulb is seen through the overlying bone.

2.7. Facial nerve rerouting (Video 1)

The facial nerve is totally decompressed from the second genu to the stylomastoid foramen. Care should be taken to insure that sharp fragments of bone left from incomplete exposure of the geniculate ganglion do not lacerate the anteriorly transposed nerve.

The periosteum of the facial nerve at the stylomastoid foramen is preserved, but the fibrous attachments to the nerve in its vertical portion are sharply transected. The completely mobilized nerve is now transposed anteriorly and laterally.

The use of continuous facial nerve monitoring during this maneuver has significantly improved postoperative facial nerve function.

Before this maneuver a new fallopian canal is drilled in the zygomatic root superior to the Eustachian tube, and a vertical incision is made in the parotid gland to create a tunnel to house the repositioned nerve. The edges of the tunnel are closed around the nerve with interrupted vicryl sutures.

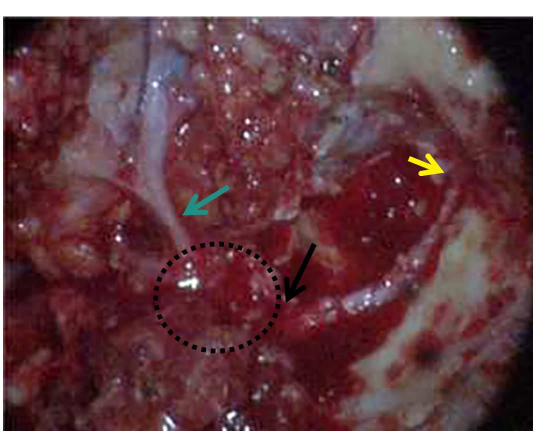

Fig. 10. A radical mastoidectomy is performed. The facial nerve is totally decompressed from the second genu (yellow arrow) to the stylomastoid foramen (black arrow). The periosteum of the facial nerve at the stylomastoid foramen is preserved (black circle). Prébifircution extracranial portion of the facial nerve (green arrow). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

By anterior transposition of the facial nerve, a direct lateral exposure of the jugular bulb is achieved. The remaining bone over the sigmoid sinus, jugular bulb and the presigmoid dura is removed. This boney removal is accomplished using a small rongeur once the drill has sufficiently thinned the bone.

The sigmoid sinus can now be exposed from the superior petrosal sinus to the jugular bulb.

2.8. Opening of the jugular foramen

After removal of the posterior border of the jugular foramen with a drill and a small Kerrison punch, the jugular foramen is widely opened, exposing the tumor in the cervical region and jugular bulb.

2.9. Tumor removal

Tumor removal is started by ligating the internal jugular vein in the neck. The internal jugular vein is double-ligated (suture/ligature) and cut. Care is taken to perform the ligation beyond any intraluminal inferior tumor extension in the neck. The jugular vein is then dissected and elevated superiorly as far as the intradural extension of the tumor toward the jugular bulb.

The sigmoid sinus is ligated with two sutures inferiorly to the superior petrosal sinus: Dural incisions are made immediately anterior and posterior to the sigmoid sinus near the junction with the lateral sinus, and well above any intraluminal superior extension of tumor. Two silk sutures are passed through one of these incisions, into the subarachnoid space medial to the sinus, and then brought out through the second dural incision, and the sinus is ligated.

The posterior wall of the sigmoid sinus is incised inferiorly from the point of sinus ligation and the intraluminal portion of the lesion is dissected from the anterior wall of the sigmoid sinus and jugular bulb. During this stage, significant bleeding can occur. However, packing with Surgicel, controls bleeding from the inferior petrosal sinus and condylar emissary vein.

The inferior pole of the tumors is dissected from the lower cranial nerves, starting in the neck and proceeding superiorly to the jugular bulb. Preservation of the anterior jugular bulb wall is helpful in preserving the lower cranial nerves. Care is taken to avoid nerve damage from excessive bipolar coagulation and over-packing with Surgicel (Fig. 11).

Finally, the anterior pole of the tumor is mobilized from the petrous internal carotid artery. During this step, bleeding from the caroticotympanic branches is controlled with bipolar coagulation. If the adventitia has been invaded, a small portion of tumor is left adherent to the internal carotid artery.

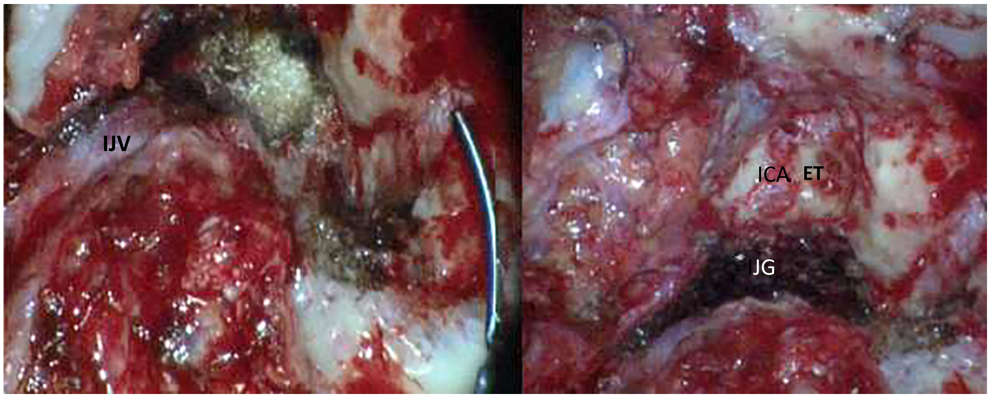

Fig. 11. End of tumor removal with preservation of the anterior wall of the jugular golf course. The internal carotid artery lies medial to the bony Eustachian tube.

2.10. Closure

Wound closure starts with Eustachian tube closure using muscle and bone wax. Abdominal fat is used to pack the surgical defect. The wound is then closed in layers.

3. Results and complications

3.1. Tumor resection

The aim of surgery is complete tumor resection. Total tumor removal was achieved in 4 patients. In the other 03 cases a subtotal resection was performed. The tumor was excised as completely as possible. The reasons of subtotal resection are involvement of the ICA and significant intraoperative blood loss.

3.2. Facial nerve function

Transposition of a normal facial nerve usually causes moderate postoperative paresis that may improve partially within 3 to 6 months (Table 3). In 1 case anatomic facial nerve was not preserved and a simple end to end suture was performed.

3.3. Caudal nerves function

In 02 cases Caudal nerves palsy was the cause of swallowing disorders resulting in dysphagia and bronchopneumonia. The deficit usually improves within 6 weeks. In 01 patient a tracheotomy and gastrostomy was necessary.

3.4. Cerebrospinal fluid (CSF) leaks

CSF leaks rarely occur after obliteration of the Eustachian tube, closure of the external auditory canal, and reinforcement of the surgical defect with abdominal fat. However, CSF leakage remains a potentially fatal complication. In our study two patients developed cerebrospinal fluid (CSF) leaks and were treated conservatively with iterative lumbar punctures.

Table 3
Pre and postoperative Facial nerve function according to the House and Brackmann (H/B) classification.

H/B	Preoperative	Immediately postoperative	12 months postoperative
I–II	16 cases	00 cases	02 cases
II–IV	00 cases	11 cases	13 cases
V–VI	00 cases	05 cases	01 case

4. Discussion

A variety of surgical approaches and radiotherapy techniques are now available to treat glomus jugulare tumors, and may even be used in combination. The decision about which procedure to use must be made on an individual patient basis, taking into account factors such as patient age, health status, desire of the patient, location and size of the tumor, and the status of the lower cranial nerves at presentation. In general, if there is no cranial nerve function for those nerves commonly involved with glomus jugulare tumors and there is evidence of tumor growth, we prefer total surgical resection if possible. If there is good function with tumor growth, total resection may be attempted, depending on tumor size and location, or a subtotal resection followed by radiation therapy for additional tumor growth may be the approach of choice. If residual or recurrent tumor is present but not growing, observation with follow-up radiological studies at regular intervals is satisfactory.

Gottfried and colleagues reviewed articles published between 1994 and 2004 that detailed use of radiosurgery or surgery to treat glomus jugulare tumors [20]. They reviewed eight radiosurgery series and seven surgical studies. They concluded that death and recurrences after these treatments are infrequent, and therefore, both treatments are considered to be safe and efficacious. They noted that although surgery is associated with higher morbidity rates, it immediately and totally eliminates the tumor. Radiosurgery results are promising, but the incidence of late recurrence is unknown. They also noted that the mechanism of growth inhibition of glomus jugulare tumors by radiotherapy is not entirely understood. Patients in the radiotherapy series included both primary treatment cases and those who had previous treatment either with surgery or other modes of radiotherapy, and rarely were the data provided separately for these two situations.

Similarly, the surgical series that they reviewed usually mixed previously untreated cases with residual or recurrence cases. Further, a wide variety of surgical approaches were used. All of this makes it difficult to directly compare reported results.

Gottfried et al. conclude that surgery remains the treatment of choice in an otherwise healthy patient who desires the immediate cure of disease provided by total resection.

Others authors have shown that with modern techniques, even the most complex glomus jugulare tumors can be totally resected with minimal complications [6,8,9,10,12,14,15].

Once the problem of the facial nerve was solved in our team, the focus attention shifted to the internal carotid artery (ICA). The presence of the ICA within the operative field, often infiltrated by tumor, is today the main factor that influences operability and our ability to achieve a gross total removal. In the case of "complex" tympano-jugular paraganglioma (10 patients), which are usually characterized by more aggressive ICA involvement, manipulation of the artery exposes the patient to extreme danger; the only reasonable option without adequate preoperative treatment is incomplete tumor removal. Some of these tumors, especially in young patients (8 patients), are very aggressive and partial removal can be counterproductive. This provided the impetus to develop and introduce endovascular techniques to manage the ICA and therefore help the surgeon remove the tumor completely with minimal morbidity and mortality. These techniques include preoperative permanent balloon occlusion (PBO) of the ICA, external-internal carotid artery bypass followed by PBO, and, more recently, reinforcement with stents [15].

5. Conclusion

The multidisciplinary approach gives the best chance of radical removal with preservation of cranial nerves, and vessels. Surgical morbidity and mortality are usually associated with damage to the lower cranial nerves. To avoid postoperative complications, an adequate surgical exposure and reconstruction of the cranial base are required.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.inat.2018.10.006.

Conflict of interest

I declare that there is no conflict of interest in my study.

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