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ORIGINAL ARTICLE

Infratemporal fossa approach type A with transcondylar-transtubercular extension for Fisch type C2 to C4 tympanojugular paragangliomas

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ABSTRACT: *Background.* The classic infratemporal fossa type A approach (IFTA-A) permits superior and anterior exposure of the jugular foramen. The transcondylar-transtubercular extension facilitates posteroinferior and medial access to the jugular foramen. The purpose of this study was to present the IFTA-A with transcondylar-transtubercular extension and to assess its surgical results.

Methods. A review of patients with tympanojugular paraganglioma who underwent resection through the IFTA-A with transcondylar-transtubercular extension was performed.

Results. In all, 39 patients were included in the study. The average follow-up was 23.6 months. Gross total tumor removal was achieved in 87.2% of the cases and there was evidence of recurrence in 5.9% of this group.

Conclusion. The transcondylar-transtubercular extension of the classic IFTA-A is aimed at making the excision of Fisch type C2 to C4 tympanojugular paragangliomas simpler and safer by drilling out one third of the lateral part of the occipital condyle and removing the jugular process and jugular tubercle. © 2013 Wiley Periodicals, Inc. *Head Neck* 00: 000–000, 2013

KEY WORDS: tympanojugular paraganglioma, glomus jugulare tumor, jugular foramen, infratemporal fossa approach, surgical management

INTRODUCTION

Tympanojugular paragangliomas (TJPs) are predominantly benign, slow-growing, highly vascularized tumors arising from paraganglia cells located within the adventitia of the dome of the jugular bulb and along the Jacobson's and Arnold's nerves, connected to venous channels.[1] These tumors tend to grow along the planes of least resistance F1 (Figure 1) by following preexisting pathways in the skull base (ie, vascular channels, neural foramina, and air cell tracts).[2] Tympanojugular paragangliomas are often locally aggressive and infiltrate the bony skull base and the regional cranial nerves (CNs). The surgical management of these lesions remains particularly challenging as a result of the complex anatomic location and potential intraoperative and postoperative complications. The major problems include: (1) adequate exposure because these tumors may spread in 3 different compartments (intrapetrous, extracranial, and intradural); (2) the vertical portion of the facial nerve being centered on and closely related to the jugular bulb; and (3) intimate relationship with important neurovascular structures, such as the lower CNs, the inferior petrosal sinus, and the internal carotid artery (ICA).[3–5] The jugular foramen area was not completely under surgeon control until the introduction of the infratemporal fossa approach type A (IFTA-A) by Ugo Fisch in 1978.[6] The IFTA-A allows superior and anterior exposure of the jugular bulb. The rationale of the IFTA-A with transcondylar-transtubercular extension is to obtain posteroinferior and medial access to the jugular bulb above the lateral mass of the atlas and occipital condyle, thus widening the exposure and facilitating venous and neural control (Figure 2). The F2 widened angle also affords better access to the petrous apex, medial to the ICA. This extension is particularly useful in cases of large tumors such as Fisch type C2 to C4 TJPs. The purpose of this study was to present the IFTA-A with transcondylar-transtubercular extension and to report the preliminary surgical outcomes obtained in 39 consecutive cases of Fisch type C2 to C4 TJPs.

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Surgical technique

The classic IFTA-A is performed as previously described.[6,7] However, we introduced some technical refinements that we would like to highlight. (1) At the beginning of the procedure, the sternocleidomastoid muscle and the posterior belly of the digastric muscle are detached from the mastoid and reflected posteroinferiorly and anteroinferiorly, respectively. This permits fast and easy identification of the extratemporal facial nerve at its exit from the temporal bone. (2) Once the anterior rerouting of the facial nerve has been accomplished, the facial nerve is allocated into a new bony canal drilled in the

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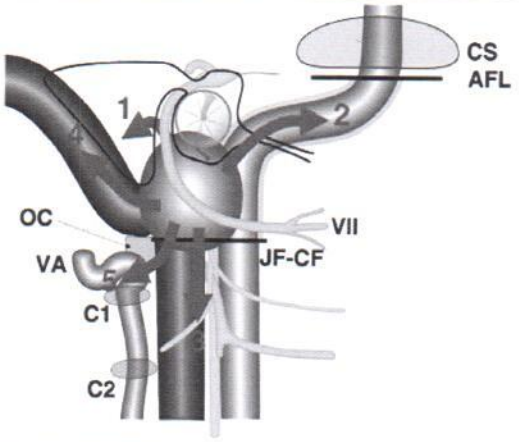

FIGURE 1. Jugular foramen paragangliomas can extend medially to become intradural, (1) anteriorly to involve the petrous apex and internal carotid artery, (2) inferiorly into the neck, (3) posteriorly along the sigmoid sinus, (4) and posteroinferiorly toward the occipital condyle and the vertebral artery (5). OC, occipital condyle; VA, vertebral artery; VII, facial nerve; C1, atlas; C2, axis; CS, cavernous sinus; AFL, anterior foramen lacerum; JF-CF, jugular foramen-carotid foramen

root of the zygoma superior to the Eustachian tube. We prefer to use fibrin glue to keep the nerve in place instead of using aluminum strips. (3) The proximal part of the sigmoid sinus is compressed extraluminally with Surgicel placed between the sinus and the overlying bone at its junction with the lateral sinus. This technique of closure of the sigmoid sinus is used instead of transdural suture ligation in order to avoid cerebrospinal fluid (CSF) leak. (4) The mandibular condyle is anteriorly displaced and taken in place by using a self-retaining retractor. We do not use the infratemporal fossa retractor to avoid injury to the transposed facial nerve. (5) It is of utmost importance not to close the external carotid artery to be able to embolize a potential recurrent tumor or an intradural tumor component before the planned second-stage operation.[8]

Once the IFTA-A has been completed, the transcondylar-transtubercular extension begins by identification of the splenius capitis muscle. Figure 3 displays a schematic presentation of the surgical steps for the transcondylar-transtubercular extension. The posterior fossa dura is uncovered toward the occipital skull base, exposing the area of the jugular process and occipital condyle. Then, the bone of the jugular process of the occipital bone and the posterolateral third of the occipital condyle are drilled. Drilling should be carried out superior to the atlanto-occipital joint and posteromedial to the jugular bulb. Bleeding from the posterior condylar emissary vein, which is usually identified posterior to the occipital condyle, is stopped by Surgicel. Removal of the jugular process permits identification of the hypoglossal canal, which is found between the jugular tubercle and occipital condyle above the vertebral artery. The hypoglossal canal runs in a posteromedial to an anterolateral direction, covered by a cortical bony layer that aids in its identification. Care is taken not to injure the hypoglossal nerve. Further extradural bone removal extends anteromedially to the jugular bulb superior to the hypoglossal canal, which represents the jugular tubercle. The jugular tubercle is located about 5 mm above the intracranial opening of the hypoglossal canal over which CNs IX to XI cross intradurally before entering the jugular fossa.[9] Removal of the jugular tubercle allows additional exposure of the tumor margins from posterior, inferior, and medial directions. The remnant of the tympanic bone and the lateral wall of the jugular bulb are completely removed. The internal jugular vein in the neck is then closed with vascular clips. When the spinal accessory nerve crosses medial to the internal jugular vein, the superior stump of the vein is pulled under the nerve and reflected upward. The tumor can now be dissected from the posterior fossa dura to the jugular bulb. The infiltrated bone of the fallopian canal, infralabyrinthine cells, and the tympanic bone is drilled away. Before starting removal, bipolar cautery is used to devascularize the tumor, minimizing the degree of bleeding from the subsequent resection. Next, the lateral wall of the sigmoid sinus and the jugular bulb are opened. Tumor dissection is performed in a piecemeal fashion using bipolar forceps or dissectors. The medial wall of the jugular bulb should be preserved, if not infiltrated, in order to preserve the lower CNs.[10] When the tumor breaches the medial wall of the jugular bulb, radical surgery requires removal of the entire bulb making the preservation of the lower CNs almost impossible. Any attempts to dissect the tumor from the involved lower CNs would result in a complete palsy, with the additional risk of leaving tumoral tissue medial to the jugular bulb. The inferior petrosal sinus is

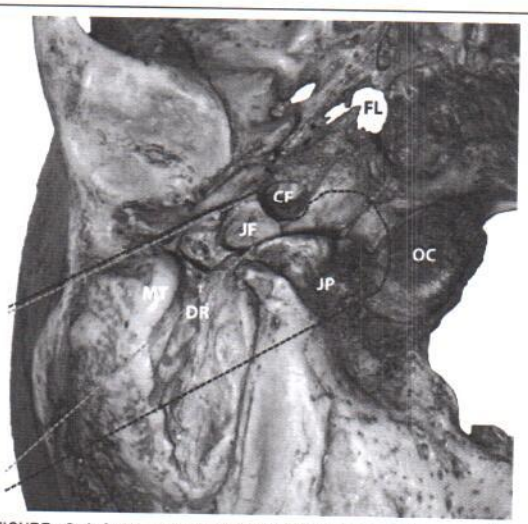

FIGURE 2. Inferior view of the skull base and comparison between the infratemporal fossa type A approach (IFTA-A; gray dashed line) and IFTA-A with transcondylar-transtubercular extension (black dashed line). In addition to the ITFA-A, drilling of the jugular process of the occipital bone and even some of the occipital condyle facilitates control of the area of the jugular bulb. CF: carotid foramen, DR: digastric ridge, JF: jugular foramen, JP: jugular process of the occipital bone, MT: mastoid tip; FL, foramen lacerum; OC, occipital condyle

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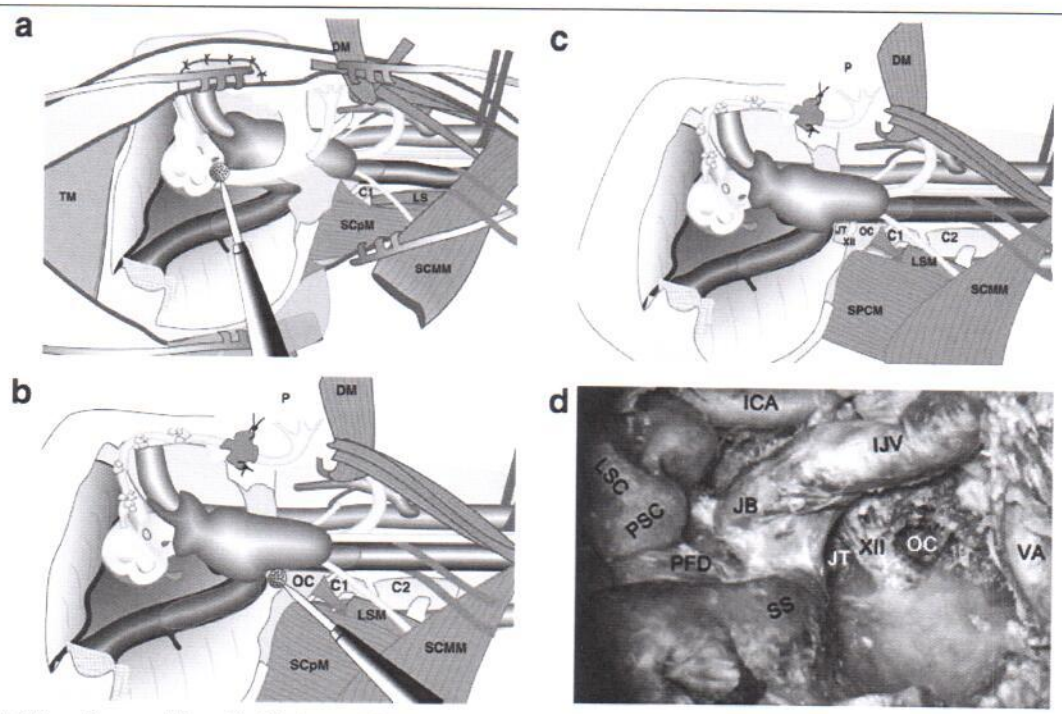

FIGURE 3. Schematic presentation of the infratemporal fossa type A approach (IFTA-A) with transcondylar-transtubercular extension. (A) The sternocleidomastoid muscle and the posterior belly of the digastric muscle are detached from the mastoid and reflected posteriorly and anteriorly, respectively. The subtotal petrosectomy is completed. The major vessels are identified in the neck and marked with surgical loops. The lower cranial nerves are identified. The sigmoid sinus is closed extraluminally. (B) The mastoid tip has been removed. Dissection of the middle and posterior fossa dura has been accomplished. Anterior rerouting of the facial nerve has been performed. The styloid process has been removed. Notice that the posterior fossa dura has been uncovered toward the occipital skull base to start drilling of the jugular process and occipital condyle. (C) After removal of the jugular process, the jugular tubercle and the hypoglossal nerve are identified. (D) Interrelationship among the jugular tubercle, hypoglossal nerve, vertebral artery, and occipital condyle. TM, temporalis muscle; DM, posterior belly of the digastric ridge; SCpM, splenius capitis muscle; C1, atlas; LSM, levator scapulae muscle; SCMM, sternocleidomastoid muscle; P, parotid; OC, occipital condyle; C2, axis; JT, jugular tubercle; XII, hypoglossal nerve; VA, vertebral artery; ICA, internal carotid artery; IJV, internal jugular vein; IX, glossopharyngeal nerve; LSC, lateral semicircular canal; JB, jugular bulb; PFD, posterior cranial fossa dura; PSC, posterior semicircular canal; SS, sigmoid sinus; VII, facial nerve

closed with Surgicel. Care must be taken when packing the inferior petrosal sinus and its branches.[11] These can be multiple and usually enter between CNs IX, X, and XI. The final stage of surgery involves the definitive management of the ICA. The extent of drilling of the surrounding bone depends on the degree of ICA involvement. Starting from the posterior within the middle ear, drilling is advanced both lateral and medial to the artery. In the majority of cases, involvement of the ICA by the tumor is limited to the subperiosteal tissue without invasion of the adventitia. In these cases, tumor dissection is started at the entrance into the skull base, where a good plane of dissection can be created between the artery and the periosteal tissue. A bipolar coagulator can be used for bloodless separation of the tumor from the artery. In the cases where the adventitia is infiltrated, subadventitial tumor dissection is required. This procedure carries a risk of injury to the ICA, especially in irradiated or previously operated cases. In such situations, preoperative stenting of involved segments of the ICA is recommended to allow safe and complete tumor removal.[12] Further drilling of all suspected bone of the infralabyrinthine and apical cells is accomplished. If required, the ICA is partially mobilized and the infiltrated clivus is drilled out. The posterior fossa dura is not opened and the intradural portion of the tumor is removed in a second stage. At the end of the procedure, the Eustachian tube is closed with periosteal tissue, any dural tears are closed with pieces of muscle, and the cavity is obliterated with abdominal fat. We do not utilize the temporalis flap for closure in order to avoid bleeding and esthetic problems. We prefer a musculofascial closure by suturing the previously detached sternocleidomastoid muscle to the temporalis fascia. In addition, the posterior belly of the digastric muscle is sutured to the sternocleidomastoid muscle. The musculofascial and cutaneous layers are sutured in a watertight fashion.

MATERIALS AND METHODS

Between April 1989 and January 2012, a total of 272 TJPs were operated on at the Gruppo Otologico. The IFTA-A with transcondylar extension has been regularly used for Type C2 to C4 tumors since 2006. The data reviewed during this period showed that 39 TJPs underwent IFTA-A with transcondylar-transtubercular extension. All patients underwent complete otologic and neurologic

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examinations, flexible fiber optic laryngoscopy, and hearing assessment by pure-tone audiometry. All patients underwent preoperative catecholamine level investigation. All patients were evaluated before surgery by high-resolution CT with bone windows, gadolinium-enhanced MRI, and 4-vessel angiography with manual cross-compression testing. Additionally, superselective tumor embolization using polyvinyl alcohol was performed 2 to 4 days before surgery. Stenting of the ICA was performed if the preoperative arteriography demonstrated clear-cut involvement of the arterial wall. In previously operated or irradiated cases with sufficient collateral circulation, permanent balloon occlusion was applied. The indication and methods of endovascular treatments have been described elsewhere.[12–15] The facial nerve function was graded according to the House–Brackmann (H–B) scale.[16] The follow-up evaluation with clinical and neuroradiologic evaluations was performed at 6 months and then yearly. The minimum follow-up period was 1 year. Patients with recurrent or residual tumors were followed closely (every 6 months) for the first 2 years and then on an annual basis.

The study protocol was approved by the institutional review board of the hospital and written informed consent was obtained from all patients.

RESULTS

General characteristics and clinical manifestations

The study group was comprised of 39 consecutive patients with TJP surgically treated by using the IFTA-A with transcondylar-transtubercular extension. There were 16 male and 23 female patients. Mean age at the time of surgery was 47.1 ± 11 (range, 25–64 years). Eighteen tumors (46.1%) were on the right side and 21 (53.9%) were on the left side. The most common presenting complaints were pulsatile tinnitus in 30 cases (76.9%), hearing loss in 29 cases (74.3%), dysphonia in 8 cases (20.5%), dysphagia in 5 cases (12.8%), and vertigo in 4 cases (10.2%). Distribution of tumors according to Fisch
T1 and Mattox classification[7] is presented in Table 1. Twenty-three lesions (59%) were exclusively extradural and 16 (41%) had both intradural and extradural extensions. Five patients presented with multicentric tumors; 3 had an ipsilateral vagal paraganglioma, 2 had bilateral carotid body tumors, and 1 had a contralateral carotid body tumor. None of the patients had catecholamine-secreting tumors. The duration of the follow-up period (consisting of clinical evaluation, hearing tests, flexible fiber optic laryngoscopy, and serial CT and/or MRI scans) of the series ranged from 12 to 61 months (mean, 23.6 ± 15 months).

Surgical treatment and tumor resection

Thirty-three patients underwent a primary operation, 5 patients presented with a recurrent tumor operated on elsewhere, and 1 patient had been previously irradiated. Nine of the 39 patients underwent preoperative endovascular treatment of the ICA by either stenting (6 cases) or balloon occlusion (3 cases). No complications occurred during endovascular treatment or during surgery in these patients. All tumors were resected through the IFTA-A
F4 with transcondylar transtubercular extension (Figure 4).

TABLE 1. Tumor classification.

Fisch class	No of ECE	De1	De2	Di1	Di2
C1	0	0	0	0	0
C2	23	6	1	6	0
C3	15	3	1	2	7
C4	1	0	0	0	1
Total	39	9	2	8	8

Abbreviations: ECE, extracranial extension; De1, intracranial/extradural extension up to 2 cm dural displacement; De2, intracranial/extradural extension >2 cm dural displacement; Di1, intracranial/intradural extension up to 2 cm; Di2, intracranial/intradural extension >2 cm; C1, no invasion of the carotid; C2, invasion of the vertical carotid canal between the foramen and bend; C3, invasion along the horizontal carotid canal; C4, invasion of the foramen lacerum and along the carotid into the cavernous sinus.

Staged surgical resection was used in 8 patients that had tumor type Di2 (intradural tumor >2 cm). Second-stage intradural removal was performed through a transcochlear approach in 4 cases, and through the petro-occipital transsigmoid approach in the remaining 4 cases. This staging strategy has been adopted to avoid the risk of having postoperative CSF leak resulting from the wide neck exposure.

Total tumor resection was achieved in 34 patients (87.2%), whereas 5 patients (12.8%) underwent a near-total resection. In 2 patients, small tumor remnants in the cavernous sinus were intentionally left behind to avoid compromising CNs III, IV, and VI. Encasement of the vertebral and basilar arteries (2 cases) and involvement of the ICA with absence of collateral flow on temporary occlusion of the ICA (1 case) were other factors that necessitated partial resection. During the course of follow-up of these residual cases, 2 (40%) did not exhibit any growth and 1 (20%) exhibited spontaneous regression at 36, 61, and 12 months after surgery, respectively. Two patients (40%) had evidence of growth at 19 and 30 months after surgery and were managed with stereotactic radiotherapy.

Recurrence was documented in 2 of the 34 cases (5.9%) of total tumor resection. One patient with type C2Di1 tumor had recurrence at the level of the petrous apex 1 year after surgery and was subjected to stereotactic radiation therapy. The second patient with type C3Di1 tumor experienced recurrence at the level of the hypoglossal canal 4 years after surgery and the tumor was resected via the previously performed IFTA-A with transcondylar-transtubercular extension.

Facial nerve outcomes

Preoperatively, 33 of the 39 patients (84.6%) had H–B grade I facial nerve function, 2 (5.1%) had H–B grade II, 1 (2.5%) had H–B grade III, and 3 (7.7%) had H–B grade VI. The 6 patients with preoperative facial nerve weakness had been previously operated on in other centers. In 8 patients, including those with preoperative facial nerve palsy, the facial nerve was resected because of tumor infiltration, and the defect was repaired using a sural nerve graft in the same sitting. At 1-year follow-up, 5 patients (62.5%) reached H–B grade III, 2 (25%) reached H–B grade IV, and 1 (12.5%) remained in H–B grade VI. The facial nerve was anteriorly rerouted in 31 of the 39 cases. Of these, 11 (35.5%) recovered to H–B grade I, 10 (32.3%) to H–B grade II, 9 to H–B grade III (29%), and 1 experienced H–B grade VI (3.2%), at 1-year follow-up.

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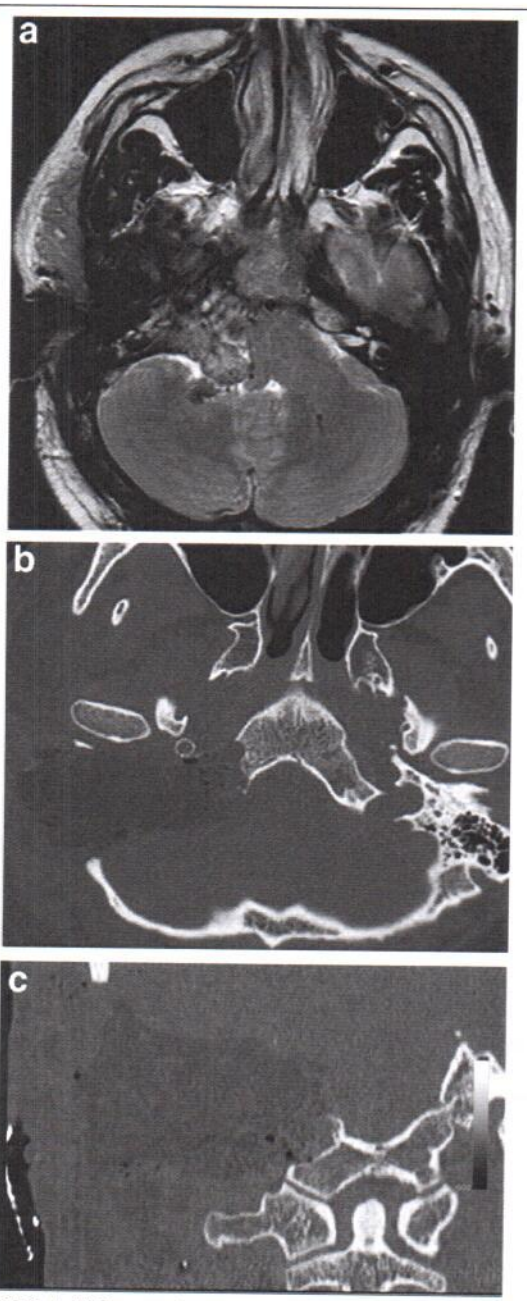

FIGURE 4. (A) Preoperative MRI showing a right-sided type C3Di2 tympanojugular paraganglioma. (B) Postoperative axial and (C) coronal high-resolution CT scans of the same case managed with infratemporal fossa type A approach (IFTA-A) with transcondylar-transtubercular extension. Notice the extent of bone removal at the level of the occipital condyle and the meshes of the stent inside the internal carotid artery

Lower cranial nerve status

Fifteen patients (38.4%) were found to be suffering from at least 1 cranial nerve deficit in the preoperative evaluation. The most common cranial nerves involved were the X (11 cases) and IX (8 cases) followed by the XII (7 cases) and the XI (6 cases). Two patients had paralysis of all 4 CNs on initial diagnosis. Twenty-four patients (61.5%) showed no lower CN palsy. Immediately after surgery, none of the patients recovered function of the preoperatively paralyzed lower CNs. A new deficit of 1 or more of the lower CNs was recorded in 18 patients (46.1%). Only 6 patients (15.3%) had no lower CN deficits. Postoperative follow-up of at least 1 year showed that the most common new CN deficit was seen in IX CN (42%), followed by X CN (23%), XII CN (23%), and XI CN (20.5%; Table 2). None of the patients required tracheotomy in this series. A prophylactic nasogastric feeding tube was required in the immediate postoperative period for those patients who developed deficits of CN IX and X. Oral intake was reintroduced on the third postoperative day in patients with preoperative paralysis and on the sixth postoperative day in the acute paralysis cases. There were 2 patients (5.1%) who experienced aspiration. Feeding by percutaneous endoscopic gastrostomy tube was used in one of these patients after she developed pneumonitis in the postoperative period, from which she recovered with conservative treatment. The percutaneous endoscopic gastrostomy was successfully removed after she developed good compensation of the contralateral vocal cord. Glottic competence was improved by performing type I medialization thyroplasty in 2 patients with noncompensated swallowing disorders. On long-term follow-up, all the other patients were able to compensate well for their lower CN deficits with the help of speech and swallowing rehabilitation. Physical therapy was administered in patients with CN XI paralysis to prevent persistent shoulder dysfunction and pain.

T2

Complications

There were no perioperative or postoperative deaths, nor cases of meningitis or vascular injury in the present series. None of the patients experienced occipitocervical instability. None of the patients required blood transfusion. Two patients experienced postoperative CSF leak requiring an additional procedure for resolution. No other complications occurred in this series.

DISCUSSION

The treatment options for patients with TJPs include surgical resection, fractionated radiotherapy, stereotactic radiation, observation with serial imaging, and a combination of these modalities.[17–19] Wait and scan policy is

TABLE 2. Preoperative and postoperative lower cranial nerves function, and number of cases that developed new cranial nerve deficit.

	No. of cases with CNDs (%)		
CN	Preoperative	Postoperative*	Postoperative new CND
IX	8 (20.5)	22 (56.4)	14 (35.9)
X	11 (44)	20 (51.3)	9 (23)
XI	6 (15.4)	14 (35.9)	8 (20.5)
XII	7 (17.9)	15 (38.4)	9 (23)

Abbreviations: CND, cranial nerve deficit; CN, cranial nerve.
* At least 1-year follow-up after surgery.

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based on the belief that TJPs are usually slow-growing lesions. This strategy might be recommended in selected cases, mainly those of elderly patients with intact lower CN function. Some authors propose stereotactic radiotherapy as a primary treatment for TJPs reporting results equivalent to surgery.[19–22] We would agree with Patel et al,[23] that ". while radiation therapy may render glomus tumor stable, it is not curative, and in the younger patients with an additional life expectancy of at least 20 years, surgical extirpation of the tumor provides the best modality of cure." In our opinion, radiotherapy might be approved as an alternative primary treatment in elderly patients with tumor progression, in patients who are medically unfit for surgery, as well as in cases with recurrent or residual tumors at the level of the cavernous sinus or with engulfment of intradural vertebral and posterior-inferior cerebellar arteries. However, indepth review of the experience with radiotherapy is beyond the scope of this article. In agreement with other authors,[2,23–30] we believe that surgical gross total resection of the tumor still remains the mainstay of treatment of TJPs, at least in young patients. The technical advances in preoperative neuroimaging and interventional neuroradiology along with the refinements in skull base microsurgery allowed removal of tumors formerly considered inoperable. Nevertheless, the complex anatomic location of these tumors, their frequent encroachment on neurovascular structures, and their potential ability to recur are some of the criteria that make the resection of these lesions particularly challenging. The ideal surgical approach should adhere to the basic tenets of obtaining a wide access to the whole tumor margins with complete control of major vessels. No general consensus has been reached on the choice of surgical approach. The most important factors determining the surgical approach are the degree of ICA involvement and the infiltrative nature of these tumors.[3,31,32] The classic IFTA-A provides superior and anterior access to the jugular foramen and infralabyrinthine areas.[6] The key point in this approach is the anterior rerouting of the facial nerve. This maneuver is essential to obtain adequate exposure and control of the intrapetrous ICA. Thus, IFTA-A is particularly indicated for removal of Fisch type C2 to C4 tumors, which are generally considered tumors with advanced level of extension and ICA involvement. Postoperative conductive hearing loss because of ear canal closure and facial nerve paresis related to the anterior rerouting of the facial nerve represent the main disadvantages of the IFTA-A. Since the introduction of the IFTA-A, several variations have been subsequently proposed and modified for dealing with TJPs.[27,33–37] During the last 20 years, literature describing limited or no facial nerve mobilization to treat TJPs progressively increased.[27,37–44] These conservative approaches can be safely considered for nonvascularized jugular foramen tumors that do not infiltrate the ICA walls (ie, lower cranial nerve schwannomas, meningiomas, and chondrosarcomas) and for Fisch type C1 TJPs (ie, with erosion of the carotid foramen with minimal vertical carotid involvement) with predominantly posterior disease.[45–47] The major limitation of these procedures is the limited access to the middle ear, horizontal petrous ICA, and petrous apex, creating the risk of residual tumor and the potential for catastrophic injury to the ICA. Short mobilization of the distal segment of the facial nerve with or without removal of the posterior canal wall can marginally improve access to the vertical segment of the ICA and the tumor in the middle ear.[48–50] However, it is still not sufficient to achieve distal ICA control. Compromising this exposure by keeping the facial nerve in place or by a short facial nerve mobilization would, in our opinion, be equivalent to a compromise of the degree of resection and safety. Oghalai et al,[37] who have an impressive series and results by using the fallopian bridge technique, state that involvement of the horizontal ICA may be better approached with anterior rerouting of the facial nerve. Management of the ICA is frequently required in Fisch type C2 to C4 TJPs and range from simple skeletonization to facilitate removal of surrounding bone, to subadventitial dissection, and to sacrifice with preoperative balloon occlusion. When the ICA is completely surrounded by tumor with severe stenosis on arteriography, manipulation without proper endovascular treatment may give raise to severe bleeding, incomplete removal, or cerebral vascular accident. Permanent balloon occlusion is performed when the ICA is infiltrated by tumor and the collateral blood flow is sufficient. In cases with insufficient collateral blood flow, we regularly use intraluminal stenting.[4,12–15]

The use of the far or extreme lateral approaches with various extensions have been proposed for the routine approach to the jugular foramen to preserve the middle ear and leave the facial nerve in situ, and even avoidance of drilling the petrous bone.[9,28,41,51–55] These approaches offer a wide posteroinferior access to the jugular foramen while keeping the facial nerve in place and preserving the external auditory canal and middle ear. In our opinion, the main drawbacks of these approaches are the limited superior and anterior access to the jugular foramen and the incomplete control of the whole intrapetrous ICA. We think that in the treatment of TJP, especially those of Fisch types C2 to C4, the use of transjugular, transcondylar, and transtubercular extensions should be used in combination with, and not as an alternative, to the IFTA-A. The classic IFTA-A provides superior and anterior access to the jugular foramen and infralabyrinthine areas, whereas the transcondylar and transtubercular extensions facilitate posteroinferior and medial access to the jugular foramen above the lateral mass of the atlas and occipital condyle. Complete control of the posteroinferior spread of the tumor is ensured by drilling the bone of the jugular process of the occipital bone and the posterolateral third of the occipital condyle. In addition, removal of the jugular tubercle provides additional exposure of the tumor margins from the posterior, inferior, and medial directions. The widened angle also affords better access to the petrous apex. By increasing the exposure, the bleeding is controlled under direct vision, rather than blind cauterization. Removal of the lateral process of the atlas and transposition of the vertebral artery is unnecessary unless extradural vertebral artery involvement is present. The IFTA-A with transcondylar-transtubercular extension represents the evolution and combination of previously described techniques, such as the transtemporal approaches and the extreme lateral approaches and its

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variants. We believe that this approach permits sufficient surgical exposure to remove the tumor safely and theoretically decreases tumor recurrence with removal of infiltrated air cells in the occipital condyle. Since 2006, we routinely perform this approach for all Fisch type C2 to C4 tumors. In the present study, total removal was reached in 87.2% of cases. These results compare favorably with other large series. Rates of total removal ranging from 65% to 85% have been reported in the literature.[56–59] In the present series, recurrence was documented in 2 of the 34 cases (5.9%) of total tumor resection. Because of the extremely long period it can sometimes take for a recurrence to occur, no definitive conclusion can be drawn at present. To minimize the risk of recurrence, all the bone surrounding the tumor should be drilled out aggressively, keeping in mind that the infiltration is often more extensive than that visible on the scans. Infiltrated bone around the jugular fossa cannot safely and adequately be removed without rerouting the facial nerve, particularly if there is anterior extension along the carotid canal, as with the majority of our cases.[3,5,37] The same is true for the tympanic bone, often infiltrated in a medial to lateral direction. Any attempt to keep the facial nerve in place and preserve the external auditory canal and middle ear contents may result in incomplete tumor removal.[32] Our facial nerve results after long and permanent anterior re-routing show recovery to H–B grade I or II in 68% of cases. These results are consistent with those reported in other series.[56–61] Temporary facial nerve palsy, with a high percentage of recovery to grade I or II at 1 year, lower CN deficits, and conductive hearing loss are the price to be paid for attempting total removal, which the authors consider the correct goal, at least in young patients. Sudden deficit of preoperative functioning lower CNs is a dreaded complication in TJP surgery and it might be followed by a number of undesirable consequences, such as dysphagia, aspiration, and dysphonia. This must be taken into consideration during the preoperative planning. Because sudden palsy of previously functioning lower CNs in elderly patients would be met with serious morbidity, watchful waiting should be adopted in the elderly, and surgery only should be indicated in case of lower CN deficits and/or impending neurologic complications.

CONCLUSION

TJPs are formidable lesions, and ongoing refinements and advances in technique are welcomed to improve the management of these tumors. We think, however, that in the treatment of TJP, especially those of Fisch types C2 to C4, the use of the transjugular, transcondylar, and transtubercular extensions should be used in combination with, and not as an alternative to, the Fisch IFTA-A. This is a standard modification that we have used over the last 6 years. This approach allows increased posteroinferior access to the jugular bulb providing a wide exposure and multidirectional control of the tumor and thus reducing bleeding and the possibility of recurrence.

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