AJNR

Selective arteriography of glomus tympanicum and jugulare tumors: techniques, normal and pathologic arterial anatomy.

J R Hesselink, K R Davis and J M Taveras

AJNR Am J Neuroradiol 1981, 2 (4) 289-297
http://www.ajnr.org/content/2/4/289

Selective Arteriography of Glomus Tympanicum and Jugulare Tumors: Techniques, Normal and Pathologic Arterial Anatomy

John R. Hesselink[1]
Kenneth R. Davis
Juan M. Taveras

Glomus tympanicum and jugulare tumors arise within the middle ear and jugular fossa, respectively, but often extend into the adjacent areas of the skull base and posterior fossa. Multiple branches of the external carotid, internal carotid, and vertebral arteries may contribute to the vascular supply of these lesions. The arteriograms of 15 patients with glomus tumors were correlated with the surgical findings to determine if selective arteriography could define precisely the involvement within the middle ear, jugular fossa, and mastoid. The arteriographic mapping correlated well with the surgical findings in nine of 13 cases that had surgery, but a few important limitations were found. Therefore, a new arteriographic projection, called a transcanalicular view, is proposed that separates the middle ear from the jugular fossa, allowing for better visualization and assessment of the tumor blush.

Glomus tympanicum and jugulare tumors arise from paraganglionic glomus tissue within the middle ear and jugular fossa. Improved microsurgical techniques in association with preoperative embolization have allowed complete resection of these vascular tumors in many cases with minimal blood loss [1, 2]. Previous reports have described successful embolization of glomus tumors [3–7]. Selective arteriography is mandatory to define precisely the location and extent of these tumors for such treatment. In this report, we describe the arteriographic techniques, propose the optimum radiographic positions, review the complex arterial anatomy of the region, and evaluate the arterial pedicles of glomus tympanicum and jugulare tumors.

Anatomy

In 1953, Nager and Nager [8] made an elegant investigation of the arteries of the middle ear by tracing the arteries through serial microscopic sections (figs. 1A and 1B). Holgate et al. [9] also summarized the vascular supply to the temporal bone. Three arteries provide the major vascular supply to the middle ear: (1) the inferior tympanic, (2) anterior tympanic, and (3) stylomastoid. The superior tympanic, caroticotympanic, and the artery of the eustachian tube also make significant contributions. The arteries of the middle ear anastomose extensively with each other. The vascular territories of the various arteries are illustrated in figures 1C and 1D.

The inferior tympanic artery is most often a branch of the ascending pharyngeal artery. On occasion it arises from the occipital artery or it may have a common origin with the posterior auricular artery.

The anterior tympanic and deep auricular arteries most commonly arise from the internal maxillary artery just proximal to the superficial temporal artery, but may also arise from the middle meningeal, deep temporal, or inferior alveolar arteries [10]. These arteries may have a common origin and are very difficult to separate even on magnification angiography. The deep auricular artery gives a

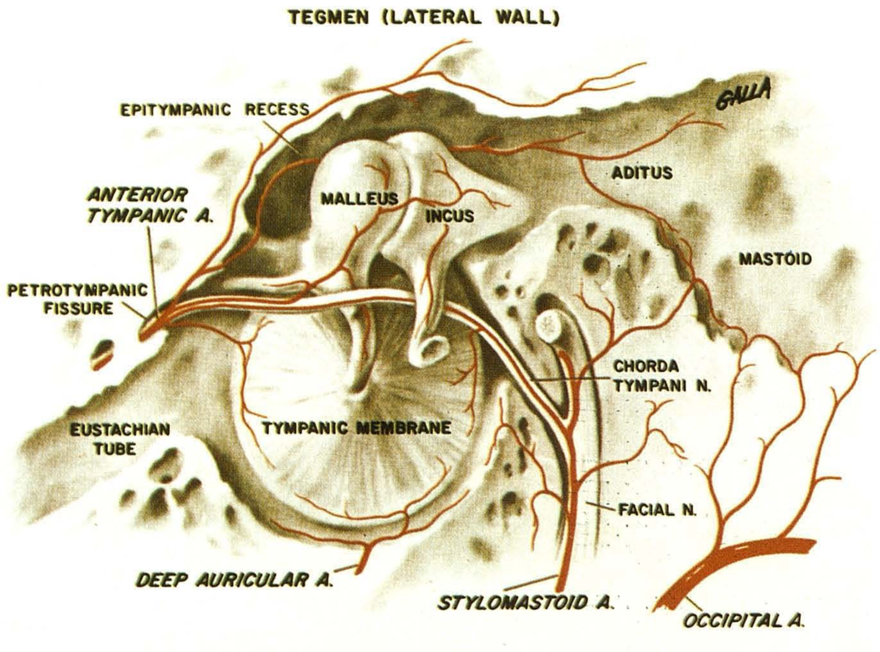
Received December 31, 1980; accepted after revision March 10, 1981.

Presented at the annual meeting of the Radiological Society of North America, Dallas, TX, November 1980.

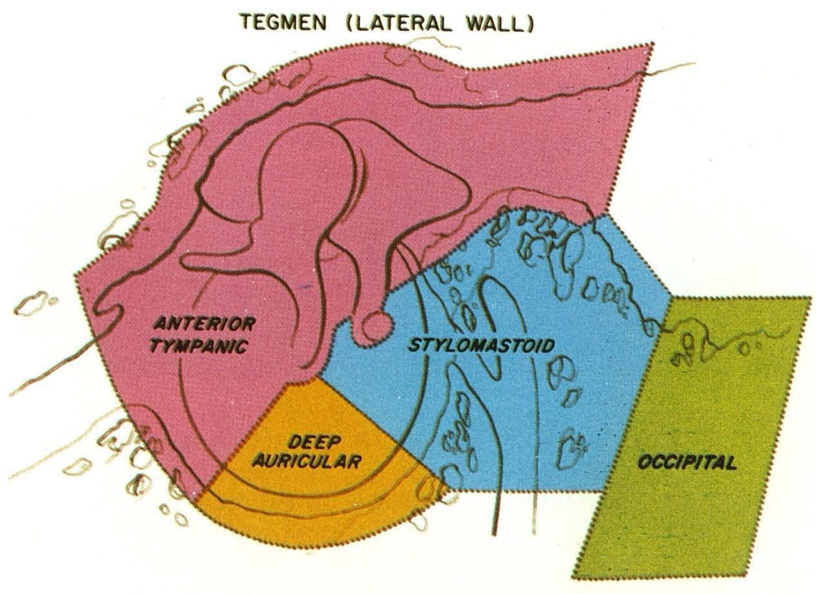
This work was supported in part by the Mallinckrodt Company, St. Louis, MO.

[1]All authors: Department of Radiology, Section of Neuroradiology, Harvard Medical School, and Masschusetts General Hospital, Boston, MA 02114. Address reprint requests to J. R. Hesselink.

AJNR **2:289–297, July/August 1981**
0195–6108/81/0204–0289 $00.00

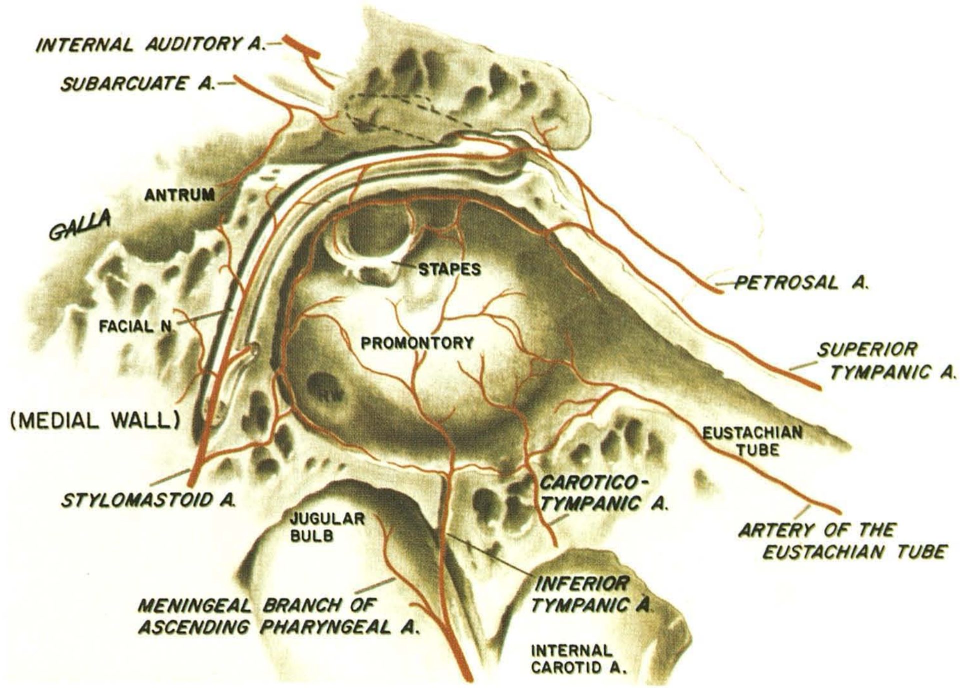


1A

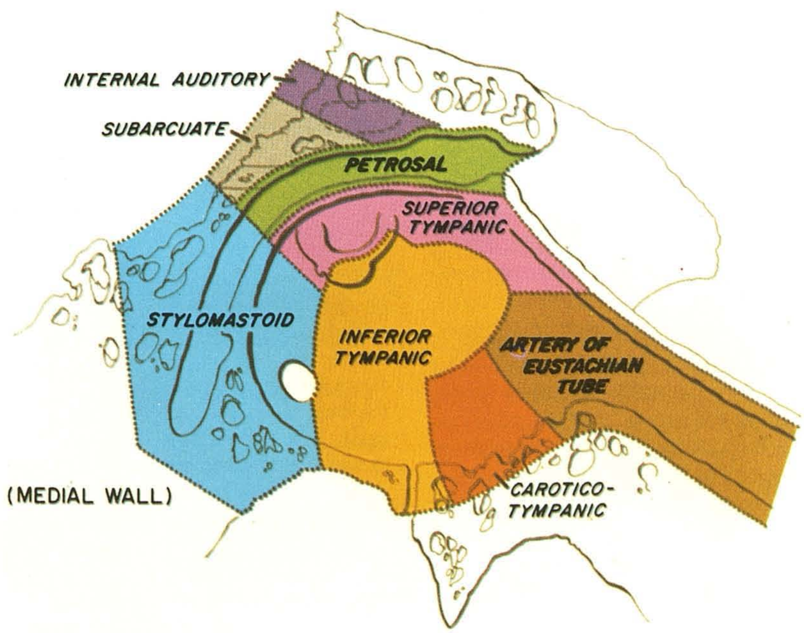


1C

Fig. 1.—Arteries of lateral (**A**) and medial (**B**) walls of middle ear and adjacent mastoid and jugular fossa (modified from [8]). **C** and **D**, Approximate arterial territories.


INTERNAL AUDITORY A.
SUBARCUATE A.
ANTRUM
GALLA
STAPES
PETROSAL A.
FACIAL N
PROMONTORY
SUPERIOR TYMPANIC A.
(MEDIAL WALL)
EUSTACHIAN TUBE
CAROTICO-TYMPANIC A.
STYLOMASTOID A.
JUGULAR BULB
ARTERY OF THE EUSTACHIAN TUBE
INFERIOR TYMPANIC A.
MENINGEAL BRANCH OF ASCENDING PHARYNGEAL A.
INTERNAL CAROTID A.

1B


INTERNAL AUDITORY
SUBARCUATE
PETROSAL
SUPERIOR TYMPANIC
STYLOMASTOID
INFERIOR TYMPANIC
ARTERY OF EUSTACHIAN TUBE
(MEDIAL WALL)
CAROTICO-TYMPANIC

1D

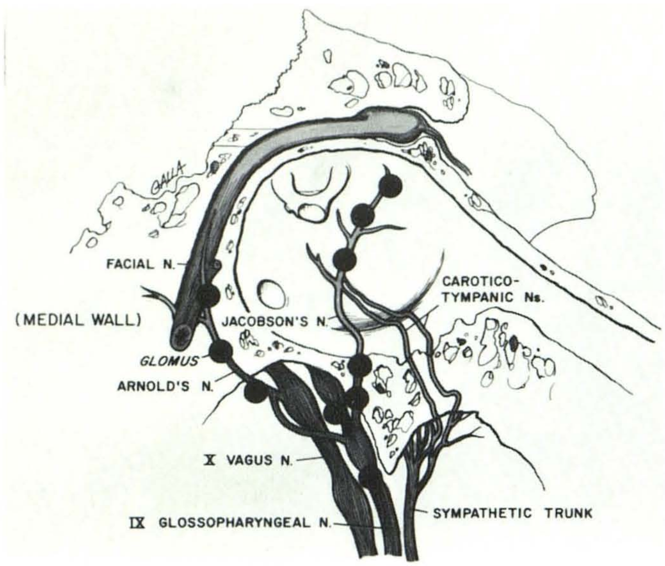


Fig. 2.—Nerves and glomus tissue in jugular fossa and middle ear. Glomus bodies (*solid areas*) concentrated in adventitia of jugular bulb, over promontory in relation to Jacobson nerve and along nerve of Arnold.

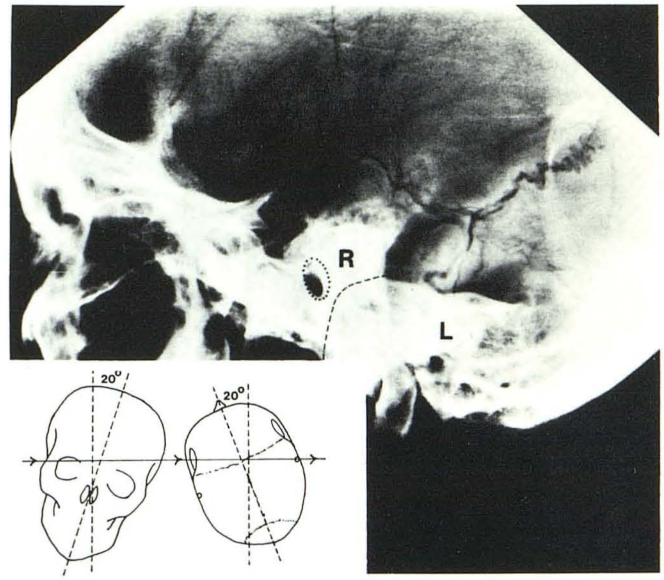


Fig. 3.—Transcanalicular view. Lateral projection with head rotated 20° contralateral and tilted 20° away from side of lesion. Middle ear of side of interest (*dotted oval*) projected slightly anterior and superior to jugular fossa (*dashed line*). R = right petrous bone; L = left petrous bone.

significant vascular supply to the external auditory canal and outer vascular ring of the tympanic membrane. A small branch courses medially beneath the tympanic membrane to supply the lateral floor of the middle ear cavity. It may or may not contribute to the inner vascular ring of the tympanic membrane. The deep auricular artery also anastamoses with the anterior tympanic artery anterior to the tympanic membrane [8].

The stylomastoid artery arises from the occipital artery in 60% of cases and from the posterior auricular artery in 40% [10]. Within the facial canal, it gives rise to the posterior tympanic artery, which follows the chorda tympani nerve into the middle ear. The superior tympanic and petrosal arteries arise from the middle meningeal artery just above the foramen spinosum and run with the greater and lesser petrosal nerves, respectively, to reach the middle ear [8].

The origin of the artery of the eustachian tube is more complex. At least four arteries anastomase near the pharyngeal end of the auditory tube, including the ascending pharyngeal artery, accessory meningeal artery, vidian artery, and pharyngeal branch of the distal internal maxillary artery. One or more of these vessels may contribute to the artery of the eustachian tube [10–13].

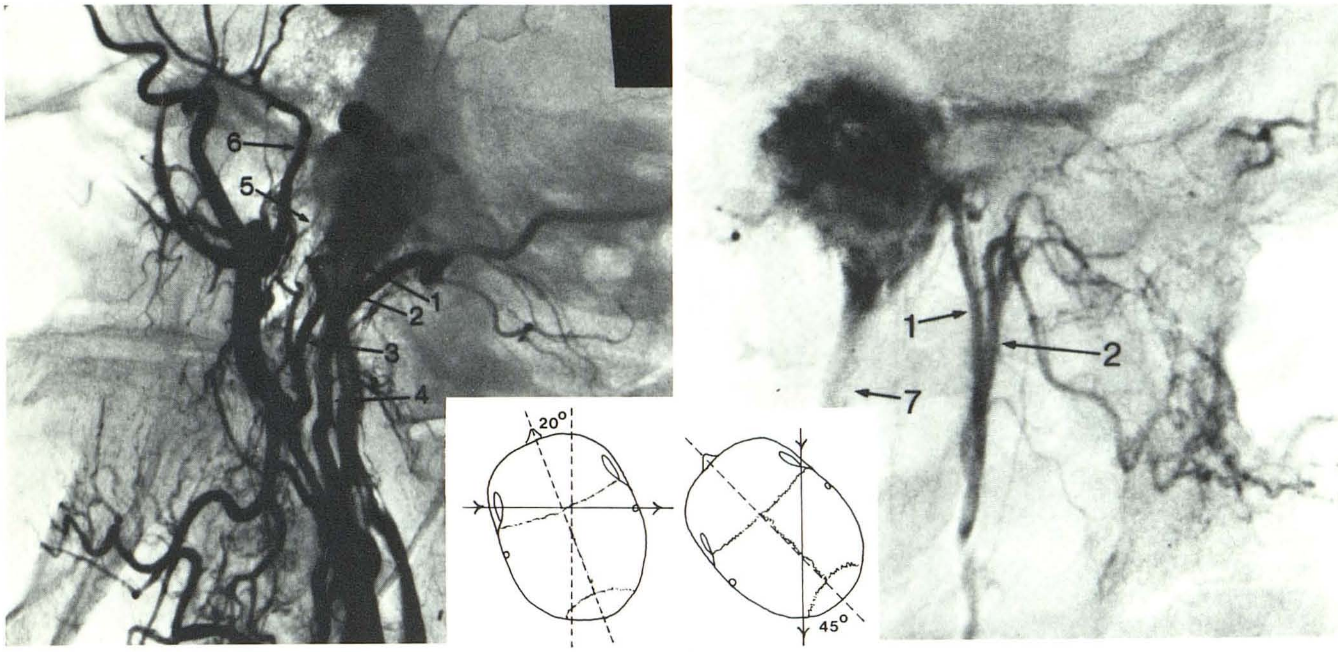
The blood supply to the facial nerve is derived from the stylomastoid, petrosal, and internal auditory arteries (fig. 1B). The superior tympanic artery may supplement or replace the contribution of the petrosal artery [8, 14, 15].

In a careful anatomic study of 88 ears in 1953, Guild [16] found the glomus bodies closely associated with the Jacobson nerve (tympanic branch of the glossopharyngeal nerve) in 54% and the Arnold nerve (auricular branch of the vagus nerve) in 46% (fig. 2). Both nerves are supplied by the inferior tympanic artery, a branch of the ascending pharyngeal artery (fig. 1B). The inferior tympanic artery travels with the Jacobson nerve through Jacobson canal to reach the middle ear [8]. Guild also noted that some or all of the glomus bodies along the Arnold nerve were actually innervated by an anastomotic branch from the inferior ganglion of the glossopharyngeal nerve. One-half of the glomus bodies were located within the adventitia of the jugular bulb in the posterior lateral part of the jugular fossa [16]. Of note is that this is close to the stylomastoid foramen and stylomastoid artery.

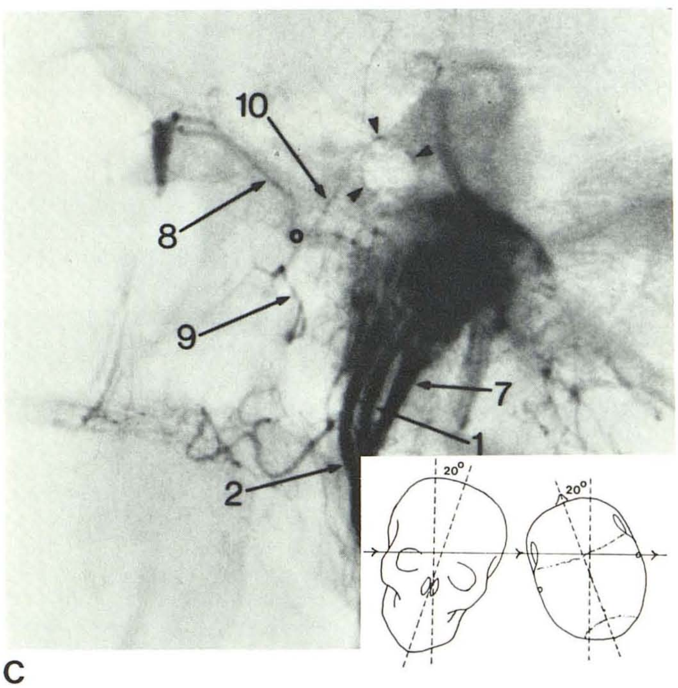
Materials and Methods

The arteriograms of 15 patients with glomus tympanicum and jugulare tumors at Massachusetts General Hospital and Massachusetts Eye and Ear Infirmary were reviewed to determine the arterial supply of these lesions. Selective arteriography was performed in 10 cases. Several radiographic projections were used to determine the best views for identifying the feeding arteries and the tumor blush. The arteriograms were correlated with the surgical findings to see if the arteriograms could define precisely the involvement within the middle ear, jugular fossa, and mastoid regions. Two patients did not have operative intervention.

Technique. To permit selective catheterization of small feeding arteries, we prefer a 4 French polyethylene catheter with a slight bend in the distal 1 cm to aid in directing the tip. With a Seldinger technique, a 4 French Teflon thick wall dilator is introduced into the femoral artery using a 20 gauge Potts-Cournand needle (Becton-Dickinson, Rutherford, N.J.) and a 0.064 cm guide wire (TSFNB, Cook, Inc., Bloomington, Ind.). The dilator is exchanged for a thin wall 4 French polyethylene dilator, and the guide wire is exchanged for one of a 0.081 cm size (TSFNB). The dilator is removed and the 4 French polyethylene curved catheter is inserted. This technique allows for minimum trauma to the artery and the delicate catheter. An alternative method is to use a coaxial sheath introducer. After the catheter is manipulated into the external carotid artery, only a very flexible guide wire (TSFB, Cook) is used for further selective catheterization of the external carotid artery branches.



A B



C

Fig. 4.—Glomus jugulare: jugular fossa, facial canal, internal auditory canal, hypotympanum. **A**, External carotid arteriogram, lateral view with 20° contralateral head rotation. Tumor blush positioned between middle meningeal and occipital arteries. Superficial temporal artery has rotated anterior to middle meningeal artery. Arterial feeders include ascending pharyngeal, stylomastoid, and anterior tympanic arteries. Anteroposterior oblique (**B**) and transcanalicular (**C**) views of selective ascending pharyngeal injection. Enlarged inferior tympanic artery. Transcanalicular view projects tympanic cavity above jugular fossa. Vascular ring (*arrowheads*) within middle ear. Artery of eustachian tube opacified even though tumor does not involve protympanum. 1 = inferior tympanic artery, 2 = anterior trunk of ascending pharyngeal artery, 3 = stylomastoid artery, 4 = occipital artery, 5 = anterior tympanic/deep auricular artery, 6 = middle meningeal artery, 7 = draining vein, 8 = vidian artery, 9 = accessory meningeal artery, 10 = artery of eustachian tube, small circle = vascular ring about pharyngeal end of eustachian tube.

Initially, external carotid arteriography is performed in two projections to identify the arterial feeders to the tumor. For the lateral projection, the head is rotated 20° contralaterally. This projects the petrous bone in a window between the superficial temporal and occipital arteries. The anterior tympanic, inferior tympanic, and stylomastoid arteries are best separated on this view. The superficial temporal artery is also projected anterior to the middle meningeal artery, giving an unobstructured view of the middle meningeal branches to the petrous bone. The proximal ascending pharyngeal artery is partly obscured by the external carotid artery, but the ascending pharyngeal artery is seen well on the anteroposterior oblique view, which is made with the head rotated 45° contralaterally and the central ray parallel to Reid baseline. The contralateral head rotation moves the teeth away from the ascending pharyngeal artery. The external carotid, occipital, and posterior auricular arteries may be superimposed on this view. Alternate biplane filming is possible with a C-arm angiographic unit. After positioning for the lateral projection, the C-arm is rotated 35° in the appropriate direction to achieve the 45° anteroposterior oblique view.

For the selective injections the same views are used except on the lateral view the head is also tilted 20° away from the side of the lesion. This can also be done by angling the lateral tube and changer. On this view, the middle ear cavity is projected slightly above and anterior to the jugular fossa. In addition, the middle ear is viewed through the external auditory canal (transcanalicular view) (figs. 3 and 4).

The ascending pharyngeal, occipital, and posterior auricular arteries can usually be catheterized selectively with little technical difficulty. The injection rate and volume of contrast material are adjusted according to the size of the artery. Selective middle meningeal injection is usually necessary to visualize the superior tympanic and petrosal arteries. The anterior tympanic and artery of the eustachian tube usually cannot be selectively catheterized. To better visualize these arteries, the catheter is positioned just proximal to the origin of the superficial temporal artery.

TABLE 1: **Relative Importance of Arterial Pedicles**

Arterial Pedicle	No. Cases (*n* = 15) in which it: Supplied the Tumor	Was Major Contributor
Inferior tympanic	13	12
Meningeal branch of ascending pharyngeal	6	1
Stylomastoid	12	9
Mastoid branches of occipital	5	2
Anterior tympanic/deep auricular	3	1
Superior tympanic	2	1
Petrosal branch of middle meningeal	3	1
Artery of eustachian tube	1	0
Caroticotympanic	3	0
Vertebral	1	0
Posterior inferior cerebellar	1	0
Anterior inferior cerebellar	1	0

A selective internal carotid arteriogram is essential to detect any contribution from the carotiocotympanic artery. A vertebral arteriogram also must be obtained to rule out posterior fossa extension. Furthermore, the vertebral artery may occasionally assume part of the territory normally supplied by the ascending pharyngeal artery.

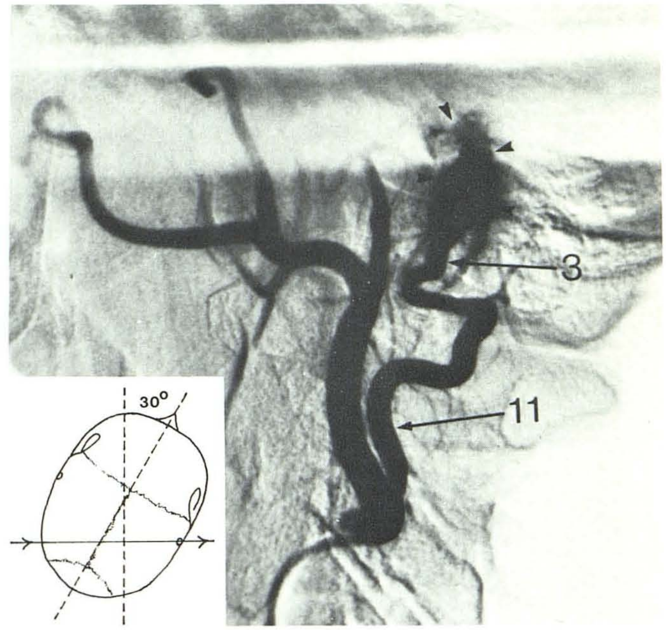


Fig. 5.—Glomus jugulare: jugular fossa, mastoid tip, posterior middle ear, facial canal. External carotid arteriogram. Markedly enlarged stylomastoid artery supplies tumor (*arrowheads*) in jugular fossa region. No arterial supply evident from ascending pharyngeal artery. 3 = stylomastoid artery, 11 = posterior auricular artery. Tumor stain well seen on this oblique lateral view, but middle ear cannot be separated from jugular fossa.

Results

Our experience is summarized in table 1. Good or excellent arteriograms were obtained in 11 of 15 cases. Three of the other four arteriograms were obtained before 1975, when the special technique was developed. In the other case, tortuous arteriosclerotic arteries precluded a selective study.

The deep auricular artery could not be identified separately on the arteriograms and was therefore grouped with the anterior tympanic artery. However, these two arteries may have a common origin. The anterior tympanic artery can be distinguished if the chorda tympani branch is identified.

Four glomus tumors were supplied by a single arterial pedicle, three by the inferior tympanic artery and one by the stylomastoid artery. Two of the three tumors supplied by the inferior tympanic artery were glomus tympanicum tumors confined to the middle ear. The other was a glomus jugulare tumor that extended deep into the petrous bone. There probably were other arterial pedicles that were not identified on the arteriogram, which was not of good quality. The tumor supplied by the stylomastoid artery was centered around the stylomastoid foramen, vertical facial canal, posterior middle ear, and adjacent jugular fossa. The other 11 tumors had two or more arterial pedicles.

In the two cases that had no contribution from the inferior tympanic artery, the stylomastoid artery was the major arterial feeder (fig. 5). One was associated with a facial nerve palsy.

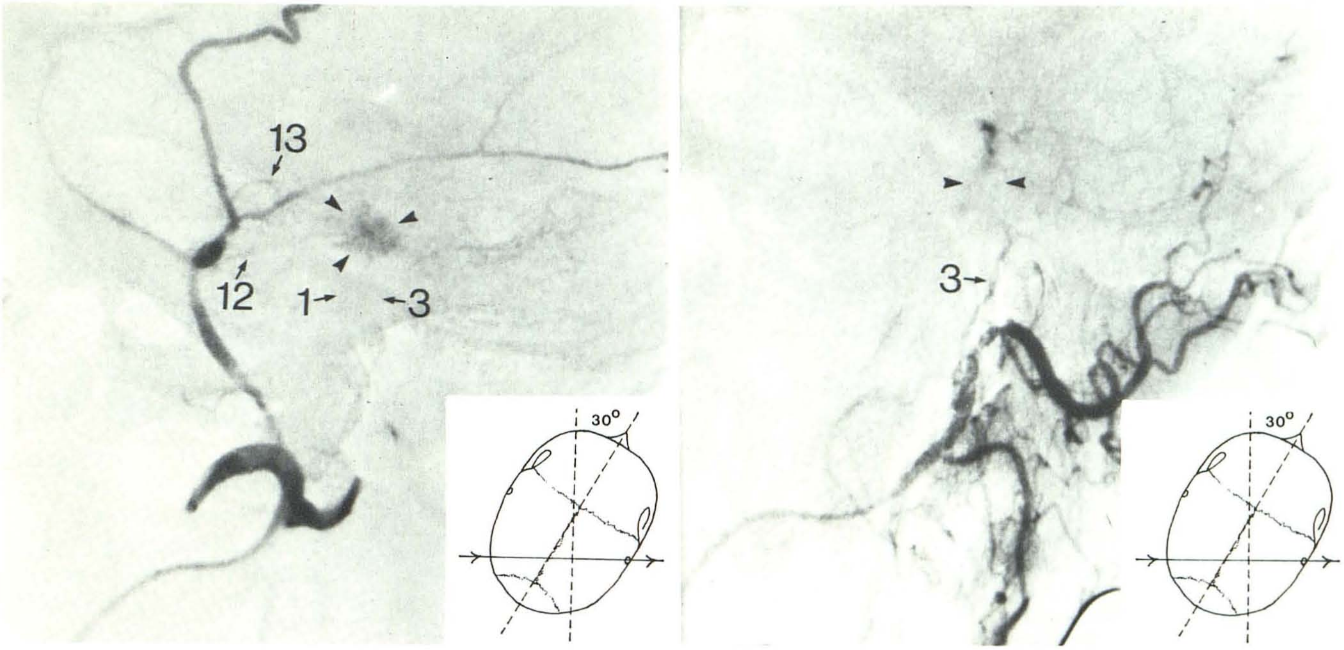
There was good correlation between the surgical findings and the arteriographic mapping in nine cases. In two of these cases, extension to the carotid canal could not be evaluated because the internal carotid artery was not studied. Of the four cases with some discrepancy, one had an inadequate surgical description, two had poor or fair arteriograms, and in the other an injection of the middle meningeal artery with the catheter in a wedged position resulted in collateral filling of multiple arteries of the middle ear (fig. 6).

Nine of the 13 patients who had surgery had glomous jugulare tumors. Six of these extended into the middle ear, five involved the mastoid, and one extended into the posterior cranial fossa. Of the four glomus tympanicum tumors, one extended outside the middle ear and one was associated with multiple glomus tumors.

Discussion

Guild [16] first coined the term "glomus jugulare" for vascular tumors arising from the glomus tissue within the jugular fossa. After further investigation by Rosenwasser [17], the term glomus tympanicum was introduced for those tumors arising within the middle ear. The symptoms and clinical findings of these tumors have been thoroughly described in the literature [18, 19]. Conventional radiographic findings have also been reviewed [20]. A number of glomus tumors examined by selective arteriography have been reported [4–6, 9–11, 21, 22].

Preoperative localization is essential because the optimum surgical approach, particularly for glomus tympanicum, depends on the location and extent of the tumor. If the tumor is confined to the mesotympanum, a transcanalicular approach (through the external auditory canal) can be used. A hypotympanic approach is used if the tumor involves the mesotympanum and hypotympanum, but spares the protympanum. If there is posterolateral extension into the region of



A B

Fig. 6.—Glomus tympanicum: promontory, hypotympanum. **A**, Selective middle meningeal arteriogram. Small glomus tumor (*arrowheads*) within middle ear supplied by superior tympanic and petrosal arteries. Retrograde filling of inferior tympanic and stylomastoid arteries. **B**, Selective posterior auricular injection. Faint blush (*arrowheads*) supplied by stylomastoid artery. There was retrograde filling of petrosal artery on lateral view. Tumor was confined to promontory and hypotympanum. 1 = inferior tympanic artery, 3 = stylomastoid artery, 12 = superior tympanic artery, 13 = petrosal artery.

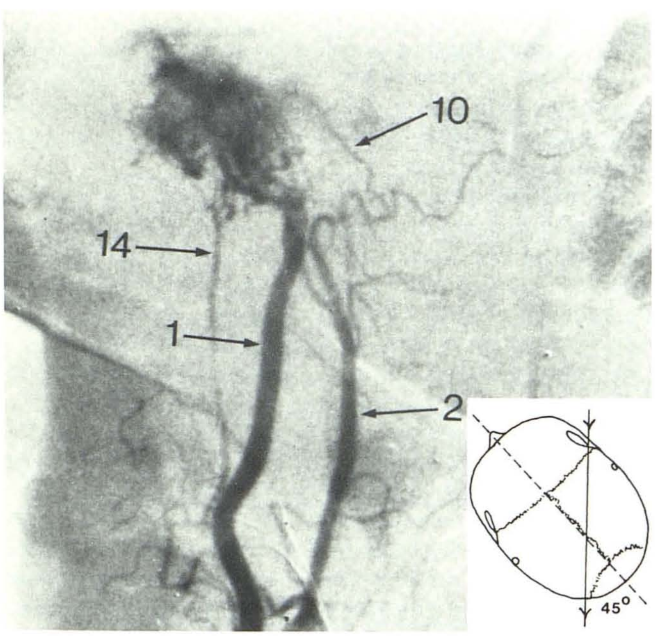


Fig. 7.—Glomus jugulare: mesotympanum, protympanum, jugular fossa. Selective ascending pharyngeal injection. Markedly enlarged inferior tympanic artery and additional supply from meningeal branch. Contribution from artery of eustachian tube indicates extension to protympanum. 1 = inferior tympanic artery, 2 = anterior trunk of ascending pharyngeal artery, 10 = artery of eustachian tube, 14 = meningeal branch.

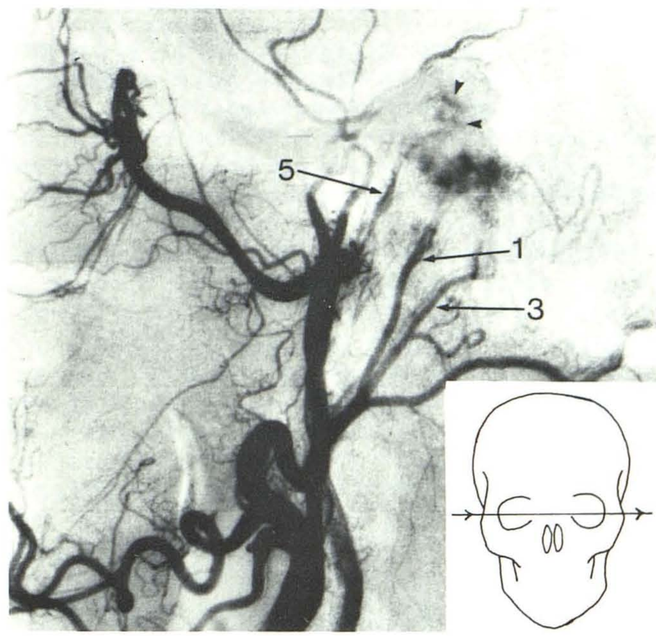


Fig. 8.—Glomus jugulare: no surgery. External carotid arteriogram. Common origin of posterior trunk of ascending pharyngeal and occipital and posterior auricular arteries. Inferior tympanic and stylomastoid arteries are major contributors to glomus tumor within jugular fossa. Tumor blush also seen within tympanic cavity (*arrowheads*). Supply from anterior tympanic artery indicates extension to lateral wall of middle ear. 1 = inferior tympanic artery, 3 = stylomastoid artery, 5 = anterior tympanic artery.

the facial canal, a radical mastoidectomy must be done along with the hypotympanic resection. The facial nerve may be surrounded by tumor without a resulting paralysis, and it is still possible in such cases to surgically exteriorize the facial nerve and achieve a complete resection [2, 20]. If the tumor extends into the protympanum or carotid canal, it is very likely unresectable [1].

Since the arterial supply to the middle ear, jugular fossa, and mastoid has been precisely mapped out [8], the extent

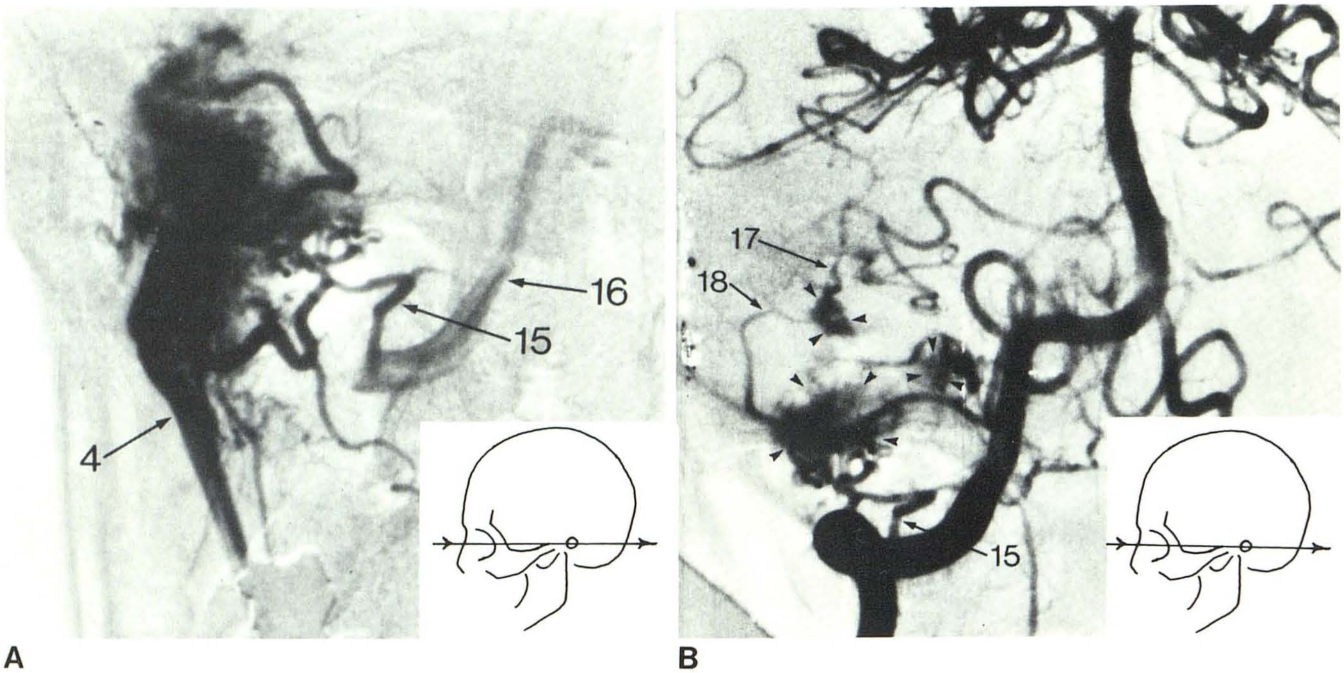


Fig. 9.—Glomus jugulare: jugular fossa, mastoid, basisphenoid, foramen magnum, middle ear. **A**, Selective occipital arteriogram. Prominent arterial supply to tumor and CI collateral to vertebral artery. **B**, Vertebral arteriogram. Contributions from anterior inferior cerebellar (AICA) and posterior inferior cerebellar (PICA) arteries indicate extension into posterior fossa. Prominent arterial supply was also seen from stylomastoid, inferior tympanic, and meningeal branches of ascending pharyngeal arteries. Tumor blush (*arrowheads*). 4 = occipital artery, 15 = muscular branch and CI collateral between occipital and vertebral arteries, 16 = vertebral artery, 17 branch of AICA, 18 = hemispheric branch of PICA.

of a glomus tumor can be determined by the arteries that supply the tumor. Since the glomus tissue is located along the Jacobson and Arnold nerves and since the inferior tympanic artery supplies both of these nerves, it is not surprising that the inferior tympanic artery is the most common arterial feeder to glomus tympanojugular tumors (figs. 4, 7, and 8). The vascular territory of the inferior tympanic artery includes the jugular bulb and fossa and the hypo- and mesotympanum. The meningeal branch of the ascending pharyngeal artery may also contribute as it passes through the jugular foramen (fig. 7). Glomus jugulare tumors readily parasitize the stylomastoid artery (figs. 4 and 8). This also is not unexpected since the glomus tissue is concentrated in the adventitia of the posterolateral jugular bulb close to the stylomastoid foramen [8]. With further posterolateral extension into the mastoid, the mastoid branches of the occipital artery may give additional supply (fig. 9A). The anterior inferior and posterior inferior cerebellar arteries contribute if there is superior extension through the jugular foramen into the posterior fossa (fig. 9B).

Glomus tympanicum tumors arise over the promontory and are supplied predominantly by the inferior tympanic artery. Posterior extension involves the territory of the stylomastoid artery. Glomus jugulare tumors usually enter the tympanic cavity through the hypotympanum and first involve the arterial territories of the inferior tympanic and stylomastoid arteries. Superior extension within the middle ear is indicated by arterial supply from the superior tympanic and petrosal arteries. Contribution from the caroticotympanic artery or artery of the eustachian tube (fig. 7) indicates involvement of the protympanum. The anterior tympanic arterial territory becomes involved by erosion of the ossicles or extension of tumor to the lateral wall of the middle ear and aditus (figs. 4 and 8). The deep auricular artery becomes a factor when there is extension of tumor into the external auditory canal.

The arteriographic mapping correlated well with the surgical findings in nine of 13 cases that had surgery. However, there are a few important limitations to the technique of determining the extent of the glomus tumor solely on the basis of the arterial supply. The inferior tympanic artery supplies both the middle ear and the jugular fossa. Therefore, extension of a tumor from the jugular fossa to the middle ear or vice versa cannot be determined from the arterial pedicle alone. A similar problem exists with the stylomastoid artery because it supplies the middle ear, facial canal, and mastoid. Furthermore, a glomus jugulare tumor may extend anteriorly to involve the carotid canal and caroticotympanic artery territory without involving the middle ear. Finally, there are extensive arterial anastomoses within the middle ear, and a wedge injection of a single feeder may result in collateral filling of other arterial territories (figs. 4C and 6).

For these reasons, the information about the arterial pedicles must be correlated with the location and extent of the vascular blush. To do this, the middle ear cavity must be separated from the jugular fossa. We have found the transcanalicular view the best to accomplish this (fig. 3). This view projects the middle ear cavity slightly anterior and superior to the jugular fossa. Also the middle ear is viewed through the window of the external auditory canal. The subtraction artifact from the base of the skull is diminished.

Other views are less useful. A straight lateral view produces profound petrous subtraction artifacts. Ipsilateral rotation on the lateral view often projects the superficial temporal artery over the middle ear and jugular fossa. We have not found a base view very helpful.

Most glomus jugulare tumors involve multiple arterial territories by the time they are detected, whereas glomus tympanicum tumors are seen earlier and may have a single arterial pedicle. In two of the glomus tumors, the major arterial pedicle was the stylomastoid artery, and there was no contribution from the inferior tympanic artery (fig. 5). Both tumors involved the posterior middle ear, vertical part of the facial canal, and adjacent jugular fossa. These tumors probably arose from the glomus tissue associated with the nerve of Arnold within the petrous bone or wtihin the facial canal (fig. 2).

These observations bring up two important points. First, although both tumors were called glomus jugulare, this is really a misnomer, since they very likely did not arise within the jugular fossa or bulb. Second, it is interesting that the inferior tympanic artery did not supply either of these tumors even though the classical anatomists state that the inferior tympanic artery supplies both the Jacobson nerve and the nerve of Arnold [16]. The data from these two cases suggest that although the inferior tympanic artery supplies the nerve of Arnold within the adventitia of the jugular bulb and jugular fossa, when the nerve enters the petrous bone and facial canal, its blood supply is assumed by the stylomastoid artery. It is known that the stylomastoid artery supplies both the vertical part of the facial nerve and the adjacent petrous bone [8].

An understanding of the arterial anatomy reveals some clinical implications for embolization of glomus tympanicum and jugulare tumors. Since the petrosal and stylomastoid arteries supply the facial nerve, there is a higher risk of producing a facial nerve paralysis when embolizing these arteries, particularly when using liquid embolic agents. Also, due to the rich anastamoses between arteries within the middle ear, over-injection of liquid embolic agents into any one artery with a wedged catheter or balloon occlusion could result in compromise of the facial nerve. If an occipitovertebral anastamosis exists and the stylomastoid artery arises from the occipital artery, selective catheterization of the stylomastoid artery or temporary occlusion proximal to the anastamosis is imperative for safe embolization.

REFERENCES

1. Spector GJ, Maisel RH, Ogura JH. Glomus tumors in the middle ear: I. An analysis of 46 patients. *Laryngoscope* **1973**;83: 1652–1672
2. Schuknecht HF. *Pathology of the ear*. Cambridge, MA: Harvard University, **1974**:23–40, 420–424
3. Hilal SK, Michelsen JW. Therapeutic percutaneous embolization for extra-axial vascular lesions of the head, neck and spine. *J Neurosurg* **1975**;43:275–287
4. Manelfe C, Djindjian R, Picard L. Embolisation par catheterisme femoral des tumeurs irriguees par l'artere carotide externe. *Acta Radiol* [*Suppl*] (Stockh) **1975**;347:175–186
5. Moret J, Roulleau P, Poncet E, Vignaud J. Interet de l'arteriographie therapeutique dans le traitment des glomus tympano-jugulaires. *Ann Otolaryngol Chir Cervicofac* **1977**;94: 491–498
6. Lacour P, Doyon D, Manelfe C, Picard L, Salisachs P, Schwaab G. Treatment of chemodectomas by arterial embolization (glomus tumors). *J Neuroradiol* **1975**;2:275–287
7. Hekster REM, Luyendijk W, Matricali B. Transfemoral catheter embolization: a method of treatment of glomus jugulare tumors. *Neuroradiology* **1973**;5:208–214
8. Nager CT, Nager M. The arteries of the human middle ear, with particular regard to the blood supply of the auditory ossicles. *Ann Otol Rhinol Laryngol* **1953**;62:923–949
9. Holgate RC, Wortzman G, Noyek AM, Makerewicz L, Coates RM. Pulsatile tinnitus: the role of angiography. *J Otolaryngol* **1977**;6:49–62
10. Djindjian R, Merland JJ. *Super-selective arteriography of the external carotid artery*. Berlin: Springer, **1978**:14–123, 251–333
11. Lasjaunias P, Moret J. Ascending pharyngeal artery. Normal and pathological aspects. *Neuroradiology* **1976**;11:77–82
12. Baumel JJ, Beard DY. The accessory meningeal artery of man. *J Anat* **1961**;95:386–402
13. Gray H. *Gray's anatomy*. Warwick R, Williams PL, eds. Philadelphia: Saunders, **1973**:1017–1071, 1138–1146
14. Lasjaunias P, Moret J. Normal and non-pathological variations in the angiographic aspects of the arteries of the middle ear. *Neuroradiology* **1978**;15:213–219
15. Blunt MJ. The blood supply of the facial nerve. *J Anat* **1954**;88: 520–525
16. Guild SR. Glomus jugulare in man. *Ann Otol Rhinol Laryngol* **1953**;62:1045–1071
17. Rosenwasser H. Glomus jugulare tumors. *Arch Otolaryngol* **1968**;88:3–40
18. Gonsalves CG, Briant TDR. Chemodectomas of the head and neck. *J Can Assoc Radiol* **1979**;30:109–115
19. Lederer FL, Skolnik EM, Soboroff BJ, Fornatte EJ. Nonchromaffin paraganglioma of the head and neck. *Ann Otol Rhinol Laryngol* **1958**;67:305–331
20. Britton BH. Glomus tympanicum and glomus jugulare tumors. *Radiol Clin North Am* **1974**;12:543–551
21. Theron J, Lasjaunias P, Moret J, Merland JJ. Vascularization of the posterior fossa dura mater. *J Neuroradiol* **1977**;4:203–224
22. Jordan CE, Newton TH. Internal carotid artery supply to temporal bone chemodectomas. *Neuroradiology* **1975**;223–257