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High-Resolution CT Investigation of Nonchromaffin Paragangliomas of the Temporal Bone

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Twenty-six cases of surgically verified nonchromaffin paragangliomas (NCPs) of the temporal bone were investigated by contrast-enhanced, thin-section, multiplanar high-resolution computed tomography (CT). Based on the high-resolution CT findings the tumors were classified according to a recently introduced surgical classification of NCP into four main types (A, B, C1–C3, and D1–D3). With high-resolution CT tumors were correctly classified in all cases, as was shown with intraoperative correlation. On the basis of these findings, high-resolution CT should replace conventional tomography and should be regarded as complementary to selective angiography in the preoperative evaluation of NCP.

Nonchromaffin paragangliomas (NCPs) (also called glomus tumors or chemodectomas) of the temporal bone are slow-growing, usually benign, locally invasive, and difficult-to-treat tumors that originate either from tympanic or jugular glomus bodies [1–3]. Selection of the surgical approach for NCPs depends on their size and extension [4, 5]. Fisch [6] classified NCPs into four main types, according to their location, size, extension, and degree of involvement of surgically important intratemporal structures. In his consecutive series of 72 surgically treated NCPs this classification proved highly useful, since it guided the selection of the appropriate surgical approach, enabled radical tumor removal, and contributed to a significant reduction of operative morbidity.

Classification of NCP of the Temporal Bone [6]

Type A tumors are localized in the tympanic cavity and are removed by conventional tympanoplastic techniques.

Type B tumors are localized in the tympanomastoid area and are removed by conventional tympanoplastic techniques.

Type C tumors involve the jugular foramen and bulb and show variable degrees of extension into the infralabyrinthine compartment of the temporal bone. Type C tumors are radically removed by the infratemporal fossa approach. Depending on the degree of involvement of the carotid canal, type C tumors are further classified into three subtypes, C1–C3. For each subtype a specifically modified infratemporal fossa approach is used for radical tumor removal.

Type D tumors extend into the intracranial space. Depending on the size of the intracranial part, type D tumors are further classified into three subtypes, D1–D3. Type D1 tumors (smaller than 2 cm) are radically removed by the infratemporal fossa approach; type D2 tumors (greater than 2 cm) are removed by a combined, two-stage otologic and neurosurgical approach; and type D3 tumors are regarded as inoperable.

Conventional polytomography for evaluation of intratemporal bone changes and selective angiography for assessment of tumor vascularity and size are complementary methods for the preoperative evaluation of NCP [7–10]. High-resolution computed tomography (CT) of the temporal bone performed with the expanded-number range–target reconstruction technique [11] has proved highly accurate in imaging anatomic detail [12, 13] and in detecting various intratemporal lesions [14, 15]. These facts prompted us to apply high-resolution CT in the preoperative investigation and classification of NCP. In this report the high-resolution CT findings for each type of NCP we observed are presented and discussed.

Materials and Methods

Between January 1980 and July 1982 we examined 26 surgically verified cases of NCP by high-resolution CT. Thin, overlapping section, contrast-enhanced multiplanar high-resolution CT was performed. All tumors underwent selective angiography, which confirmed in each case the presence of NCP. With the exception of two tumors of type D3 all other tumors were surgically verified. The extension of each tumor as assessed at operation was correlated with the extension of each tumor as observed on high-resolution CT.

Results

Based on high-resolution CT findings the 26 tumors were classified according to the system presented above. Correlation with the intraoperative findings in 24 tumors proved the CT classification to be correct in all operated cases.

Two tumors were classified as type A. In both cases a small soft-tissue, intensely enhancing mass was seen in the middle ear cavity, with the medial border of the mass broadly attached to the promontorium of the cochlea. In one case the medial interior tumor border was also attached to the intact lateral wall of the vertical segment of the carotid canal (fig. 1). There was no destruction of bone evident on high-resolution CT.

Two tumors were classified as type B. In both cases coronal sections showed a mottled-appearing infiltration of the bone plate, which separates the jugular bulb from the hypotympanon. The cortical outline of the jugular bulb was intact. A soft-tissue enhancing mass was evident in the hypotympanon (fig. 2).

Eleven tumors were classified as type C. Among these, two were...
classified as type C, five as type C, and four as type C. In both
type C tumors coronal sections showed erosion of the cortical
outline of the jugular bulb and an enhancing tumor mass in both
the hypotympanon and the jugular fossa (fig. 3). In both type C tumors
axial sections showed enlargement of the jugular foramen and
erosion of its cortical outline (fig. 4). In one case axial sections
showed an intact vertical segment of the carotid canal. In the other
case there was erosion of the posterior cortical outline of the vertical
segment of the carotid canal (fig. 5). Sagittal reconstructions proved
equally as useful as axial sections in the evaluation of the vertical
segment of the carotid canal and of the jugular spur (fig. 4).

In all type C tumors extensive erosion of the vertical segment of
the carotid canal was evident on axial sections (fig. 6). In addition,
type C tumors showed variable degrees of extension into the
infralabyrinthine compartment of the temporal bone. This was evi-
dent on both axial and coronal sections.

The four type C tumors exhibited all the criteria of type C tumors,
but showed in addition erosion of the horizontal segment of
the carotid canal. This was evident on both axial (fig. 7) and coronal
sections. In all type C tumors and in two type C tumors axial sections
showed medial extension of the tumor from the jugular
foramen into the hypoglossal canal. In these cases coronal sections
showed enlargement of the hypoglossal canal and erosion of its
cortical outline. In five of these cases sections through the tongue
demonstrated ipsilateral hypoplasia of the lingual muscles.

Eleven tumors were classified as type D. Five of these tumors
were classified as type D, four as type D, and two as type D. The
five type D, and two of the type D tumors extended from the jugular
foramen in a medial and superior direction to occupy the lateral
cerebellomodiatory cistern (fig. 8). Of these, three type D, tumors
and the two type D tumors further extended into the cerebellopon-
tine angle. One type D, and a type D tumor first involved the
internal auditory canal and then extended directly into the cerebel-
lompontine angle. Another type D tumor and a type D tumor eroded
the posterior surface of the petrous bone and extended from there
into the posterior fossa.

Discussion

Exact preoperative classification of NCP into one of the types
presented above proved to be the essential prerequisite for select-
ing and planning the surgical approach [6]. This classification
requires detailed evaluation of temporal bone involvement and
accurate estimation of tumor size. Although conventional polytom-
ography usually delineates the extent of bony destruction in the
temporal bone [7, 8] and selective angiography provides a good
evaluation of tumor size [9], neither method is sufficient for a
detailed evaluation of involvement of important intratemporal struc-
tures, such as the carotid canal, the facial nerve canal, and the
infralabyrinthine compartment of the temporal bone. Furthermore,
with conventional polytomography, because of its limited density
resolution, accurate identification of the true extent and the limits of
the intratemporal soft-tissue tumor mass is usually not possible. On
the other hand, selective angiography was shown to overestimate
the actual size of the tumor in certain cases [10].

Because of its improved density and spatial resolution, high-
resolution CT visualizes simultaneously both soft tissue and bone
structures in the temporal bone with a high degree of accuracy [11, 12]. In all of our cases high-resolution CT demonstrated both the
exact size and location of the soft-tissue tumor mass and the type
and degree of bone destruction. According to these parameters the
tumor was correctly classified in all cases, as was shown by
intraoperative correlation.

According to their sites of origin, NCPs of the temporal bone are
generally classified into two main groups, tympanic and jugular [1–
3]. While tympanic-type NCPs are confined to the middle ear cavity,
jugular-type NCPs may show variable degrees of intratemporal and
even intracranial extension. In the surgical classification presented
above, type A tumors represent tympanic NCP, while type B, C, and
D tumors represent jugular NCP, with variable degrees of intratem-
poral (types B and C–C) and intracranial (types D–D) extension.

On high-resolution CT, type A NCPs appear as homogenous,
intensely enhancing soft-tissue masses in the tympanic cavity, and
are usually broadly attached to the promontorium of the cochlea
(fig. 1). They do not cause bone erosion, but may be attached to
the lateral surface of the vertical segment of the carotid canal.

Type B tumors infiltrate the hypotympanic bone plate and extend
into the hypotympanon. For a tumor to be classified as type B, the
cortical outline of the jugular bulb must be intact. Evidence of
erosion of the cortical outline of the jugular bulb indicates tumor
extension into the jugular bulb. In order for the removal to be radical
in these cases the infratemporal fossa approach is necessary.
Therefore NCPs exhibiting type B criteria but in addition showing
erosion of the cortical outline of the jugular bulb must be classified
as type C tumors [6]. The cortical outline of the jugular bulb is best
evaluated on coronal sections performed at the level of the pars
vasculosa of the jugular foramen (figs. 2 and 3).

Type C tumors are characterized by enlargement and erosion of
the jugular foramen, variable degrees of involvement of the carotid
and, variable degrees of extension into the infralabyrinthine and
apical compartments of the temporal bone [6]. Since the shape
of the jugular foramina of both sides is frequently asymmetric, and
their sizes frequently differ, evidence of erosion of their cortical
outline is a more sensitive factor than enlargement in evaluating
NCPs. In all type C and type D tumors (22 cases) in our series
erosion of the cortical outline of the jugular foramen was found in
15 cases (68%). Axial sections proved superior to coronal for
evaluation of the jugular foramen.

Because of the central role of the carotid artery in surgery of
NCP, type C tumors were further classified into three types, ac-
cording to the degree of involvement of the carotid canal. In type C,
tumors the carotid canal may be intact (fig. 4), or there may be
minimal erosion of the posterior aspect of the cortical outline of the
vertical segment of the carotid canal (fig. 5). The cortical outline of
both the vertical and horizontal segments of the carotid canal is
best evaluated on axial sections (figs. 5 and 6). In addition, sagittal
reconstructions proved equally useful for evaluation of the posterior
wall of the vertical segment of the carotid canal (fig. 4). In type C2
tumors the vertical segment of the carotid canal is usually circum-
ferentially eroded (fig. 5). Type C tumors are characterized by
additional erosion of the horizontal segment of the carotid canal
(fig. 6). Erosion of the horizontal segment first occurs at the proximal
part of the horizontal segment and usually involves the lateral wall
(fig. 6).

Invasion into the infralabyrinthine compartment, which occurs
with type C tumors, is seen on high-resolution CT as an area of
mottled appearance of the involved bone. While axial sections show
the true extent of invasion of the infralabyrinthine compartment,
coronal sections are useful in demonstrating even minimal erosion
of bone. Type C tumors show only minimal involvement of the
infralabyrinthine compartment, limited to destruction of the jugular
spur. Type C tumors usually involve completely the infralabyrin-
thine compartment around the vertical segment of the carotid canal
and frequently extend also medially in order to involve the infra-
mental compartment (i.e., the bone plate below the floor of the
internal auditory canal).

Type C2 tumors also invade the apical compartment (the bone
space ventral to the infralabyrinthine compartment and around the
horizontal segment of the carotid canal). Type C2 and C3 tumors
frequently extend medially and erode the hypoglossal canal. This was the case in six of the nine C2 and C3 tumors of this series. Axial sections demonstrate better than coronal sections tumor extension into the hypoglossal canal. Coronal sections show in these cases enlargement and erosion of the cortical outline of the hypoglossal canal more accurately than axial sections. In cases with involvement of the hypoglossal canal, coronal or axial sections through the tongue frequently (in five of six cases in this series) show ipsilateral hypodensity. This finding was previously described and attributed to denervation hemiatrophy of the tongue [16].

Type D tumors are characterized by intracranial extension into the posterior fossa. The size of the intracranial component in type D1 tumors is less than 2 cm, and more than 2 cm in type D2 tumors. Type D3 tumors are considered inoperable because of their large extension. The tumor first extends into the extradural compartment of the posterior fossa. Since the medial border of the intracranial component of the tumor is covered by dura it is typically convex shaped, smoothly contoured, and sharply demarcated (fig. 8). Usually type D1 tumors are completely extradural. Type D2 and D3 tumors may however invade the dura and come in close contact or even adhere to the cerebellum. In three cases of this series parts of the intracranial component of the tumor were found at surgery to be located intradurally. In each of these cases CT demonstrated that one or more nodules overlaid the medial border of the tumor. We therefore suggest that a nodular appearance of the medial border of the intracranial portion of a NCP may indicate intradural extension.

Three patterns of intracranial extension were found in this series. Most commonly the tumor extends superomedially from the jugular foramen and occupies the lateral cerebellomedullary cistern. With further cranial-directed growth the tumor may occupy the cerebellopontine angle. More rarely, the tumor first involves the infralaby-
artery and tumor extension into the cavity and/or fallopian canal). Also, the tumor first involves the infralabyrinthine and inframeatal compartments and causes erosion of the posterior surface of the petrous bone. From here it extends broadly into the posterior fossa.

In conclusion, it is evident that high-resolution CT is the radiologic method of choice in providing the operative classification of NCP. This assertion is based primarily on the ability of high-resolution CT to accurately visualize the surgical important structures of the temporal bone (i.e., the middle ear cavity, the hypotympanic bone plate, the cortical outline of the jugular bulb, the jugular foramen, the carotid canal, the infralabyrinthine compartment, and the hypoglossal canal). Also important is its sensitivity in detecting even minimal erosion or involvement of these structures.

Selective angiography is complementary to high-resolution CT in the preoperative evaluation of NCP. Identification of the feeding arteries and correct localization of the tumor blush in the middle ear cavity and/or jugular fossa with the help of the recently introduced transcanalicular view allow correct estimation of size and extension of NCP in most cases [9]. Selective angiography is superior to high-resolution CT in detecting involvement of the carotid artery and tumor extension into the internal jugular vein [10].

REFERENCES