Differential Diagnosis of Jugular Foramen Lesions

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ABSTRACT

The anatomy of the jugular foramen is complex. It contains the lower cranial nerves and major vascular structures. Tumors that develop within it, or extend into it, provide significant diagnostic and surgical challenges. In this article, we describe the anatomy of the jugular foramen and outline an imaging protocol that can differentiate between lesions, thereby aiding diagnosis and facilitating management.

KEYWORDS: Jugular foramen, skull base, computed tomography, magnetic resonance imaging

The jugular foramen (JF), sometimes referred to as the posterior foramen lacerum, is situated in the floor of the posterior fossa posterolateral to the carotid canal, between the petrous temporal bone (anterolaterally) and the occipital bone (posteromedially) (Fig. 1). The term *foramen* is not strictly accurate because the JF resembles a canal with endocranial and exocranial openings. This canal is triangular in shape with its apex pointing anteromedially.¹ In a morphometric analysis, Lang and Schreiber² determined its mean dimensions as 14.5×7 mm at the internal skull base and 9×17 mm at the outer surface. The distance between the outer border of the jugular fossa and the apex of the mastoid process was 23 mm; between the outer border of the jugular fossa and the tympanomastoid suture, the distance was 15 mm. A degree of asymmetry of the JF is common and is attributed to variability in bone formation

around the primitive posterior foramen lacerum and to unequal development of the lateral sinuses.³ In most cases, the width of the right JF is greater than that of the left with no difference in length. One of the most frequently seen variations within the JF is a bony partition that has a reported prevalence of between 3.6 and 38%.^{2,4,5} An intrajugular process of the petrous bone was found in all cases, and an intrajugular process of the occipital bone was present in 30% of adult and 23.3% of pediatric specimens.²

The JF is a complex crossroad of neurovascular structures in the skull base. Anatomical variation in the course of the nerves and vessels adds to the complexity of this area. The contents of the JF are conventionally divided into the smaller pars nervosa, situated anteromedially, and the larger pars vascularis that is posterolateral, although this terminology is misleading as both contain vascular

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Figure 1 Three-dimensional volume-rendered reconstruction of the skull base using 64-slice computed tomography (CT) scanner. (A) Inferior view shows oval-shaped jugular fossa (arrow) just behind to the mastoid process. (B) Superior view shows jugular tubercle (white arrowhead) medial to the oval-shaped jugular fossa (black arrow). The impression of the hypoglossal canal (white curved arrow) is inferior and medial to the jugular foramen. The foramen lacerum (asterisk) and foramen ovale (black arrowhead) are also seen.

and neural structures. The pars nervosa contains the glossopharyngeal (IX) and Jacobsen's nerve together with the inferior petrosal sinus, whereas the pars vascularis contains the internal jugular vein, vagus (X), spinal accessory (XI), and Arnold's nerve. The IX nerve is situated anterosuperomedially to the X and XI nerves. The IX, X, and XI nerves run through the JF in a connective tissue layer that attaches the dura matter intracranially to the pericranium extracranially. This so-called "guide plate" is usually situated between the area of the JF and the inferior petrosal sinus and has an opening for the

inferior petrosal sinus, usually between the IX nerve and the X nerve. The IX nerve and/or the inferior petrosal sinus may take course through separate foramina. Tekdemir et al¹ reported the presence of a dural septum separating the IX from the X and XI cranial nerves. The posterior meningeal artery also traverses the JF. This artery is usually a branch of the ascending pharyngeal artery.² Rhoton and Buza⁶ have found that it is derived from the anterior inferior cerebellar artery in 8% of cases.

The relationship and significance of the JF to the deep fascial planes of the neck are extremely

important because both infections and tumors in these spaces are often responsible for the radiographic changes. In addition, lesions distant from the skull base in the lower face can pass through it by tracking cephalad along these potential spaces. The middle layer of the deep cervical fascia (buccopharyngeal fascia) lies anteromedially, the deep layer of the deep cervical fascia (prevertebral fascia) lies posterolaterally, and the superficial layer of the deep cervical fascia lies laterally. All these fasciae form the carotid space.

CLASSIFICATION OF THE JUGULAR FORAMEN LESIONS AND RADIOGRAPHIC DIAGNOSTIC APPROACH

A large number of lesions may develop or are found in the JF. They arise from structures normally found within the foramen or from adjacent tissues; in other words, either intrinsically or extrinsically.⁷

The identity of most lesions can be determined by a combination of spiral computed tomography (CT) and magnetic resonance imaging (MRI). Computed tomography is useful for analysis of JF bony margins as well as of adjacent skull base foramina. Tumor calcification and hyperostosis are well demonstrated with this form of examination. Magnetic resonance imaging with gadolinium shows the characteristics of a tumor, its vascularization and extension and its relationship to neighboring structures. Tumor delineation can be improved using fat-suppression sequences. Magnetic resonance angiography (MRA) or venography can help to demonstrate the type of the tumor vascularization and its local venous circulation. Digital subtraction angiography (DSA) is a prerequisite in patients with extremely vascular lesions for which preoperative embolization might be appropriate. Because the skull base presents an undulating surface and is relatively thin, section thickness must be kept to a minimum (i.e., 3-mm sections on MRI and thinner axial reconstructions of the spiral CT

data). Coronal images are essential because the plane of the JF approximates the axial.

INTRINSIC JUGULAR FORAMEN LESIONS

Parangliomas (Glomus Jugular Tumors)

The most common tumor to develop in the JF is a paraganglioma. Paragangliomas in the skull base are ubiquitous in their distribution and arise from paraganglia or glomus cells situated at the following sites: (1) in the adventitia of the jugular bulb beneath the floor of the middle ear, (2) in the bony walls of the tympanic canals related to the tympanic branches of the IX and X nerves, and (3) in the bone of the promontory, close to the mucosal lining of the middle ear. Imaging studies are necessary to depict the location and extent of tumor involvement, to help determine the surgical approach, and to predict operative morbidity and mortality. Balloon test occlusion is performed if the internal carotid artery is involved or encased. Preoperative embolization for large paragangliomas is also useful to reduce both bleeding and surgical time.

Glomus jugular tumors are not encapsulated and tend to infiltrate connective tissue planes. They have a distinctive pattern of spread that helps to differentiate them from other intrinsic tumors in this region. Glomus jugular tumors follow the path of least resistance including mastoid air cell tracts, vascular channels, the eustachian tube, and neural foramina.^{8,9} As a result, they produce an irregular JF spine (in the early stage of the disease) or a characteristic “moth-eaten” pattern of destruction in the temporal bone; both are best appreciated by high-resolution (HR), thin-section axial CT images using bone windows (Fig. 2). Other key features are dehiscence of the floor of the tympanic cavity and proliferation into the tympanum, causing destruction of the ossicles and encasement of the carotid crest. In some, destruction of the bony labyrinth and extension into the cerebellopontine

Figure 2 Computed tomography (CT) and angiographic images of glomus jugular tumor arising in the right jugular foramen. (A) Soft tissue axial postcontrast CT demonstrates a glomus jugular tumor on the right side with small intracranial extension. (B) Bone-windowed axial CT image (after contrast agent administration) shows a large expansile mass in the right jugular fossa protruding into the right hypotympanum. Note the infiltration of the vertical carotid canal, as well as "moth-eaten" borders of the adjacent petrous bone and clivus. (C) Three-dimensional volume rendered image (viewed from above) constructed from spiral CT data (bone-algorithm) illustrating the extent of bone destruction around the right jugular fossa (arrowheads). Compare with the contralateral normal structures. (D) Selective external carotid artery angiogram of the same patient (lateral view) is shown. The characteristically hypervascular tumor with a coarse blush is supplied by the hypertrophic ascending pharyngeal artery and the occipital artery (arrows). Note the early draining vein during the midarterial phase.

or cerebellomedullary angle is seen.^{8,10} The tendency of glomus jugular tumors to erode bone helps differentiate them from glomus tympanicum tumors, which are generally smaller and arise from the cochlear promontory, enveloping but not usually destroying the ossicular chain. Unfortunately, occasional cases are still found where the differential cannot be made, and in these the term *glomus jugulotympanicum tumor* is used.

The size of the tumor would seem to be inversely related to postoperative cranial nerve preservation.^{8,9} Specific imaging criteria that may help predict the status of the cranial nerves are intradural extension and configuration of the medial border of the tumor in the JF. When the tumor extends intradurally, it tends to insinuate itself among the delicate fascicles of the involved nerves. Removal of tumor requires considerable manipulation of the

Figure 3 Glomus jugular tumor of the left jugular foramen. (A,B) Axial T1-weighted images before (A) and after (B) gadolinium administration and fat-suppression show invasive, slightly hyperintense lesion with marked enhancement in postcontrast images. Note the typical “salt-and-pepper” appearance of the tumor in the postcontrast image. (C) Coronal T2-weighted image demonstrates the tumor’s pattern of spread inferiorly and laterally to the middle ear cavity. The tumor did not involve the inner ear.

nerves that often results in functional impairment and disruption.¹¹ When MRI and CT scans demonstrate that the medial border of the tumor is indistinct, there is a high probability that the tumor has infiltrated the cranial nerves in the JF. The presence of a sharp medial tumor border may indicate that the cranial nerves are separable from the tumor, although this is not an absolute predictor. The radiologist should delineate the exact extent of bone destruction and soft tissue mass to establish the likely boundaries of any surgical resection.

Another hallmark of a glomus jugular tumor (in both CT and MRI modalities) that will help differentiate it from other tympanic mass (e.g., cholesteatoma) is its strong enhancement with contrast, which is indicative of hypervascularity. Glomus jugular tumors give an MR appearance known as the “salt-and-pepper” pattern^{12,13} on long TR–long TE images (Fig. 3). The “pepper” component is caused by multiple areas of signal void, interspersed with the “salt” component, which is caused by hyperintense foci produced by slow flow

or subacute hemorrhage on both long TR and short TR images. This appearance, usually seen in tumors larger than 1 cm, is highly suggestive of a glomus tumor but can also be seen in other hypervascular lesions, such as metastatic hypernephroma and metastatic thyroid carcinoma. After radiotherapy, the tumor may shrink and have reduced T2 signal intensity and fewer flow voids. Magnetic resonance angiography is a useful tool in differentiating glomus jugular tumors from other lesions particularly if they are > 1.5 cm.^{14,15} It has been said that glomus jugular tumors are the only neoplasms of the skull base to exhibit the “dropout” phenomenon (seen in time-intensity curves) after intravenous injection of high-dose gadolinium (0.3 mmol/kg).¹⁴ Furthermore, MR venography can assist to differentiate a glomus jugular tumor from a non-neoplastic vascular anomaly (i.e., jugular venous thrombosis). Compared with CT, MRI of glomus jugular tumors is more sensitive and is capable of detecting small paragangliomas (< 5 mm) and involvement of the internal carotid artery and internal jugular vein.^{12,15}

With angiography, glomus jugular tumors (Fig. 2) appear rather coarse (due to rapidly draining veins) and have a shorter blush time than meningiomas. Their most common feeding vessels arise from the ascending pharyngeal artery and supply the inferomedial tumor compartment. The posterior auricular, stylomastoid, and occipital arteries supply the posterolateral tumor compartment. Large paragangliomas may derive further feeding vessels from branches of the internal maxillary, internal carotid, or even from the contralateral carotid and vertebral, via meningeal or pial arterial branches. Pial artery supply indicates transdural spread. Retrograde jugular venography is no longer used because intravenous tumor extension can be seen with MR venography.

Neural Sheath Tumors

Neural sheath tumors, such as schwannomas and neurofibromas, share a common site of development in the JF. The clinical presentation of neural sheath

tumors of the JF varies significantly according to the tumor's growth pattern.^{16,17} Deafness, vertigo, and ataxia are common symptoms in patients with an intracranial extension. A review of the surgical literature¹⁸ indicated that 25 of 27 patients with schwannomas of the JF had symptoms of decreased hearing. The literature is replete with comments of how often neural sheath tumors of the JF have been confused with vestibular schwannomas.^{18,19} This appears to be a common reason for inappropriate imaging techniques and subsequent misinterpretation by the radiologist, who may have been misled by the history and imaging request. Hoarseness and weakness of the trapezius and sternocleidomastoid muscles are often seen in patients whose tumor is within the bone of the skull base or has extended below it.

Samii et al²⁰ categorized JF neural sheath tumors into four groups: type A, tumors primarily in the cerebellopontine angle with minimal enlargement of the JF; type B, tumors primarily in the JF with intracranial extension; type C, extracranial tumors with extension into the JF (and with clinical signs of XII nerve involvement); and type D, dumbbell-shaped tumors with both intra- and extracranial components.

There are characteristic CT and MRI appearances of neural sheath tumors that aid differential diagnosis. In nonenhanced CT images, neural sheath tumors are isodense to the brain parenchyma and are almost indistinguishable from it. After contrast, they appear as well-demarcated vascular tumors (Fig. 4). Coronal images reconstructed from raw spiral CT data offer the advantage of an insight into the intra- and extracranial parts of the tumor. Bone-windowed images show a smoothly scalloped, well-corticated enlargement of the JF in contrast to the moth-eaten pattern that is seen with paragangliomas (Fig. 2) or the irregular osteolytic destructive pattern of metastases or lymphomas. Unfortunately, asymmetries in the size of the JF are present in a large number of normal patients, and this can cause some confusion. Furthermore, primarily intracranial (type A) and extracranial (type C) tumors may not produce enlargement of the JF.

Figure 4 Schwannoma of the left jugular foramen (JF). (A) Bone-windowed computed tomography (CT) images demonstrate significant enlargement of the JF on the left side. The jugular spine is well delineated. Compare with the “moth-eaten” pattern of Fig. 2B. (B,C) Adjacent axial CT images after contrast agent administration show a fairly well-enhanced lesion (arrow) in the left JF extending extracranially and compressing the neighboring jugular vein (curved arrow). The patient complained of a hoarse voice for 5 months. The schwannoma can be classified as type C. (From Samii M, Babu RP, Tatagiba M, Sepehrnia A. Surgical treatment of jugular foramen schwannomas. *J Neurosurg* 1995;82:924–932.)

Matsushima et al²¹ reported that all neural sheath tumors show low uniform T1-weighted intensity (usually matching that of the brain), high T2-weighted signal, and marked (or moderate) contrast enhancement. Neural sheath tumors do not generally show internal flow voids, although flow voids may be seen at the periphery of some relatively vascular vestibular schwannomas. If in doubt, DSA will differentiate between glomus jugular and neural sheath tumors on the basis of relative vascularity. Other distinguishing features

are the absence of vascular pedicle(s) and jugular bulb compression with neural sheath tumor. Glomus jugular tumors have pronounced vascular pedicles and often invade the jugular vein with intraluminal growth (Fig. 4).

Meningiomas

Meningiomas develop from the leptomeninges. They are defined as primary when centered in the

Figure 5 Primary meningioma of the right jugular foramen (JF) (intrinsic lesion). (A) Axial computed tomography (CT) scan with contrast agent shows a large, centrifugally growing, nonhomogeneously enhancing lesion in the right cerebellopontine angle, the JF, and the infratemporal fossa. The ventral borders of the tumor are ill defined, indicating an infiltrative pattern of spread toward the nasopharynx. (B) Coronal CT image with contrast agent and bone-algorithm reconstruction demonstrates a sclerotic jugular fossa on the right side in which the normal architecture has been maintained. The dumbbell-shaped tumor shows a broad dural attachment intracranially, and this provides an important differentiating imaging feature.

JF (intrinsic lesions) and secondary when centered in the posterior fossa with extension into the JF. Primary meningiomas of the JF are characterized by an invasive growth pattern with extensive skull base infiltration. Accurate preoperative diagnosis has important prognostic and therapeutic implications. Secondary meningiomas of the JF appear to behave quite differently.

Two growth patterns are recognized, centrifugal and en plaque. Centrifugal growth takes place in all directions and involves the middle ear, the jugular tubercle, hypoglossal canal, occipital condyle, and clivus. Extrinsic spread inferiorly into the nasopharynx and carotid space may be seen. Further spread superiorly along the intracranial dural reflections is characteristic of en plaque growth (Figs. 5 and 6). Theoretically, the pattern of spread allows differentiation between primary meningiomas, neural sheath tumors (schwannomas), and paragangliomas within the JF. As previously mentioned, paragangliomas typically involve the

hypotympanum superolaterally with limited involvement of the carotid space inferiorly. Only infrequently do they extend medially into the jugular tubercle, hypoglossal canal, and clivus.²² Unlike paragangliomas, JF schwannomas follow the course of the IX, X, and XI cranial nerves from the lateral aspect of the brainstem (superomedially), with variable inferior spread into the nasopharynx and carotid space of the suprahyoid neck. However, the pattern of spread is not totally reliable and cannot form the basis on which to make the distinction between these entities.

With CT, the meningiomas are isodense to the brain and may be difficult to see on standard imaging protocols. After contrast agent administration, marked enhancement is the rule (Fig. 5). The signal intensity with MRI varies on T1- and T2-weighted images, depending on the histological pattern, and they may be indistinguishable from other JF lesions. It is reported that, compared with schwannomas, meningiomas usually have a lower

Figure 6 Secondary meningioma of the right jugular foramen (JF) (extrinsic lesion). Axial T1-weighted post-gadolinium magnetic resonance image shows a small meningioma (arrow) originating from the right JF (arrow-head) and extending medially into the cerebellopontine angle cistern (not shown) with an en plaque growth pattern. The tumor lacks the "salt-and-pepper" pattern of paragangliomas. Note the presence of a "dural tail" sign.

T2-weighted signal and a higher precontrast CT attenuation.²³ A recent study by Shimono²⁴ et al demonstrated differences in MR signal intensity and contrast enhancement between the intra- and extracranial components of JF meningiomas. The signal intensity of the extracranial component was higher on T1-, T2-, and postcontrast T1-weighted images. It was suggested that this might be attributable to differences in the ratio of meningioma cells and interstitial bundles of collagen between intra- and extracranial components of meningioma. A reliable imaging feature of meningiomas is partial calcification and infiltration of the diploic spaces within the skull base. This gives rise to character-

istic hyperostosis,²⁵ which has a distinctive appearance compared with the bone destruction caused by paragangliomas and scalloping of the foramen by neural sheath tumors (Fig. 5).

Metastatic Tumors

Metastases—usually from primary tumors in the lung, breast, and prostate—give rise to destructive lesions that infiltrate the JF (Fig. 7).²⁶ These tumors give similar signal to muscle on T1-weighted images together with low-intensity cortical bone signal. An irregular contour of the foramen is usually seen on CT images. Metastases usually lack high signal on T2-weighted images or have flow voids unless they are extremely vascular.

Retrograde perineural spread from malignancies of the face and oral cavity may give rise to JF metastases. Lymphoma, melanoma, and squamous cell carcinoma show this type of tumor extension. Enlargement and pathological enhancement of the nerve root, as well as JF enlargement, are suggestive of perineural spread (Fig. 8). This pattern may also be apparent in patients with neuritis or secondary edema, both of which may cause some enhancement. The key concept that indicates perineural spread is effacement or obliteration of the normal fat pad that is present at the extracranial opening of the JF.

Primitive Neuroectodermal Tumor

Primitive neuroectodermal tumor (PNET) is an uncommon intrinsic JF tumor that usually presents with a progressive bulbar palsy.²⁷ The imaging characteristic of these tumors is an irregular destructive mass surrounded by irregularly eroded bone. Primitive neuroectodermal tumors may give slightly high signal on T2-weighted images, be isointense in T1-weighted images, and give homogeneous enhancement after administration of gadolinium. No tumor blush is elicited on angiography.

Figure 7 Metastasis of breast cancer in the left jugular foramen. (A) Axial soft tissue algorithm postcontrast computed tomography (CT) demonstrates hypodense tumor located in the left jugular fossa extending into the ventral aspect of the petrous bone. The CT image shows unequivocal tumor invasion of the jugular bulb, which is critical for selection of the surgical approach. Infiltration of the posterior aspect of the longus colli muscle is probable. (B) The corresponding bone-windowed image clearly shows demineralization of the adjacent petrous apex, which has irregular borders.

Trauma and Other Rare Intrinsic Lesions

Localized bone destruction of the JF may result from trauma. In the presence of a skull base fracture, with or without a dural tear and cerebrospinal fluid (CSF) leakage, bone-windowed, high-resolution CT with multiplanar reconstructions is the imaging of choice. A suspected dural tear is best evaluated with thin-section CT. Contrast administration is not necessary because the fracture indicates where the CSF leak is, unless there is extensive damage or if the precise site of the fracture is in question. In these cases, intrathecal contrast medium may be useful. Localized bone destruction of the JF may also be caused by bone diseases such as fibrous dysplasia, Paget's disease, histiocytosis X, and multiple myeloma.

Common Misdiagnoses—Pseudomasses

Jugular bulb flow variants (e.g., slow, turbulent, jetting) are often misdiagnosed and are called pseudomasses. The various signals that are emitted by the jugular bulb (commonly a high signal in

T1-weighted images) catch the eye of the radiologist and may seem enhanced on postcontrast imaging due to slow venous flow. The key feature for the differential diagnosis is the signal intensity in T2-weighted images where no signal normally comes from the JF giving the impression of a "black" foramen. In rare cases where a T2-weighted signal may be seen, time-of-flight (TOF) MRA with careful examination of the source images can exclude pathology in the region (Fig. 9). If doubt remains, bone-windowed, HR CT scans with multiplanar reconstructions can clear up any problems by showing a normal, preserved jugular spine.

Anatomical variants may be misdiagnosed as pseudomasses in the JF (e.g., a high dehiscent jugular bulb). Commonly seen as an accidental finding in CT scans of the petrous bone, the high jugular bulb can be easily identified and needs documentation lest anyone wish to operate on the ear.

Vascular inflammatory lesions (e.g., internal jugular vein thrombophlebitis) present yet another diagnosis dilemma. A halo of edema around the thrombosed vein, as well as enhancement of the vessel wall and perivenous soft tissue in fat-suppressed axial MRI, is useful for differentiation.

Figure 8 Magnetic resonance imaging (MRI) of retrograde perineural spread from squamous cell carcinoma of the tongue (not shown). Postgadolinium, fat-suppressed T1-weighted MRI shows enlargement and obliteration of the left jugular fossa (arrow) with a moderately enhanced soft tissue mass. The adjacent osseous structures appear diffusely infiltrated, with partial loss of the cortex. Note the perineural spread in the hypoglossal canal (curved arrow), which was responsible for fatty infiltration and atrophy of the left genioglossus and hyoglossus muscles (not shown). Direct encroachment of the medial pterygoid and masseter muscles as well as the parapharyngeal space fat and the pharyngeal constrictor muscle is unequivocal. The MRI findings of the skull base were crucial findings and aided selection of the most appropriate treatment for the patient.

EXTRINSIC LESIONS OF THE JUGULAR FORAMEN

Extrinsic lesions involving the JF are either derived from the brain (above) or the deep facial spaces (below). These lesions could be expected to affect the temporal bone, brain, or carotid space more than the contents of the JF. In reality, extrinsic lesions often have a complex presentation and mimic intrinsic lesions of the JF. Meticulous analysis of the imaging features is therefore required. Extrinsic lesions arising from above the JF are very rare. Meningiomas are by far the most common,

followed by occasional glial tumors. Much of what has been said about JF meningiomas imaging features also applies to intracranial meningiomas. Involved bone may be permeated but is usually still intact. Erosion or some remodeling may be seen. Prolapse of meningioma into the infrajugular fossa may give rise to a palpable neck mass.

Diagnostic difficulties may also be encountered when lesions originate from the petrous bone or the clivus. This is an extremely diverse group of lesions that include chordomas, chondrosarcomas, chondroblastomas, osteoclastomas, fibrosarcomas, endolymphatic sac tumors, malignant temporal bone tumors, cholesteatoma, epidermoid tumors, cholesterol granuloma, petrositis, osteomyelitis, abscess, and mucocoeles. More rarely, lesions such as hemangioblastoma, hemangiopericytoma, lymphoma, cavernous hemangioma, amyloidoma, sarcoidosis, and papillary endothelial hyperplasia (Masson tumor) have also been described in the jugular fossa.^{28–34} Tumors frequently involving the JF from below, arising from the parapharyngeal space. These include schwannoma, lymphoma, nasopharyngeal carcinoma, perineural squamous cell carcinoma, and rhabdomyosarcoma.

Chordomas

Chordomas are rare bone tumors arising from remnants of the cranial end of the embryologic notochord. They are usually found in the clivus and sphenoid-occipital synchondrosis that extend laterally into the JF. Chordomas produce accentuated irregular bone destruction and are hypointense on T1-weighted images, markedly hyperintense on T2-weighted images, and have a typical lobulated shape with peripheral contrast enhancement where bone has been infiltrated. Intratumoral calcification is common and seen in ~50% as speckling on CT or as a signal void with MRI. Chordomas can be very large. Complete surgical resection is rarely possible, and multiplanar reconstructions of the spiral CT data are essential to appreciate the full extent of these tumors.

Figure 9 Illustrative example of pseudomass of the left jugular foramen (JF). (A) Axial T1-weighted postcontrast image shows an enlarged JF on the left side with flow-related vivid enhancement. Note the smooth, perfectly rounded outline of the hyperintensity filling the jugular bulb. (B) Three-dimensional time-of-flight venous angiography indicates a high jugular bulb on the left side. Note altered flow of the left transverse sinus, sigmoid sinus, and jugular vein, which accounts for the misdiagnosis.

Chondrosarcomas

Chondrosarcomas are assumed to arise from embryonal rests, endochondral bone, or cartilage. They are usually extradural and have a peak age of presentation between 20 and 40 years, not dissimilar to that of chordomas. Patients give a long history of headache and progressive cranial nerve deficits. Chondrosarcomas are parasellar tumors, whereas chordomas are infrasellar skull base tumors. In clinical practice, however, the topography of these large tumors is not easily distinguishable. The radiological features of chondrosarcomas are similar to those of chordomas and differentiation between the two entities is sometimes not possible on the basis of radiological appearances alone.

Inflammatory Lesions

Osteomyelitis around the JF may be unilateral and caused by otitis externa or a deep fascial abscess, or it may be bilateral and secondary to systemic infections; the latter situation has a poorer prognosis. It is

likely that a focus of infection, albeit initially quiescent, exists within the temporal bone and results in slowly progressive, destructive osteomyelitis of the skull base. Initial CT scans reveal abnormal soft tissue in this region. Magnetic resonance imaging is useful when extensive infiltration of the JF contents is clinically evident. The imaging characteristics may be similar to those of tumors, and in these cases the clinical history helps to differentiate.³⁵

Rhabdomyosarcoma

Rhabdomyosarcoma is the predominant tumor (embryonal histologic type) of the nasopharynx and masticator space in children. The tumors infiltrate the skull base and parapharyngeal tissues. Rhabdomyosarcoma is generally hyperintense on T2-weighted images and muscle isointense on T1-weighted images (Fig. 10). Although intratumoral hemorrhage is uncommon, subacute or chronic hemorrhagic foci may appear bright on T1- and T2-weighted imaging. A muscle can always be recognized as its site of origin, and the

Figure 10 Rhabdomyosarcoma in the right infratemporal fossa. (A) Nonenhanced coronal T1-weighted magnetic resonance imaging (MR) shows a well-circumscribed muscle isointense mass in the right infratemporal fossa. The mass extends into the right jugular foramen (JF) (arrow). Note the marked bilateral cervical lymphadenopathy. (B) Enhanced coronal T1-weighted MRI shows the predominately hyperintense mass extending into the JF (arrow).

tumor mass is typically homogenous with destruction of adjacent bone. Most rhabdomyosarcomas demonstrate a moderate to marked homogenous enhancement after contrast agent administration. Intratumoral calcification is rarely seen in rhabdomyosarcoma.³⁵

CONCLUSION

The JF exhibits complex anatomical relationships and contains significant vessel and neural structures. Lesions arising in the region of the JF may be classified as either intrinsic or extrinsic. In many cases, the clinical manifestations of the disease indicate the nature of the lesion. Imaging techniques offer valuable information about these lesions and helps to make a precise diagnosis. The correct diagnosis helps to avoid surgical pitfalls and optimizes management planning.

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