Irradiated Paragangliomas of the Head and Neck: CT and MR Appearance

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PURPOSE: To present the spectrum of CT and MR findings of glomus tumors of the head and neck successfully treated with radiation therapy. **METHODS:** The patient charts and all CT and MR studies of 24 patients (25 tumors) who had been successfully treated with radiation therapy were retrospectively reviewed. Eighteen patients had pre- and posttreatment imaging studies. Tumor size, internal morphology, enhancement pattern, visualization of flow voids, and bone erosion were evaluated before and after radiation therapy. Statistical evaluation of the presence of flows voids and tumor size was performed using the Fischer Exact Test. **RESULTS:** All patients had residual tumor after radiation therapy. Sixty-one percent of tumors demonstrated a reduction in size. Only one tumor with pretreatment bone destruction demonstrated healing of the bone. MR findings after radiation therapy included variable alteration in T2 signal, decreased heterogeneous enhancement, and a reduction in flow voids. There was a significant difference in the presence of flow voids based on tumor size. **CONCLUSIONS:** Successfully irradiated paragangliomas demonstrate residual masses, the presence of which does not by itself indicate treatment failure. Stabilization or reduction in size, decreased enhancement, diminished flow voids, and reduced T2 signal after radiation therapy are a result of therapy and are indicative of local control. Persistent bone demineralization and erosion without progression is commonly seen in successfully controlled tumors. Paragangliomas are relatively homogeneous in internal morphology except for areas of flow void. Flow voids are not a reliable criterion for diagnosis in lesions less than 2.5 cm.

Index terms: Paraganglioma; Therapeutic radiology; Neck, computed tomography; Neck, magnetic resonance; Neck, neoplasms

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Paragangliomas, also called glomus tumors or chemodectomas, are vascular lesions arising from the neural crest derived nonchromaffin paraganglion cells. The most common sites of occurrence in the head and neck include the carotid body, along the course of the vagus nerve, the dome of the jugular bulb, and the middle ear (1). The preferred treatment for paragangliomas has historically been surgical resection. However, a significant number of patients with glomus tumors have been treated with radiation therapy at our institution. This provides the opportunity to study the changes of imaging findings occurring in irradiated paragangliomas.

The purpose of this paper is to present the computed tomographic (CT) and magnetic resonance (MR) findings in paragangliomas at presentation and after radiation therapy.

Subjects and Methods

Fifty-five charts of patients who had previously undergone radiation therapy for treatment of head and neck paragangliomas between 1971 and 1991 were retrospectively reviewed. The population consisted of patients who elected radiation therapy as an alternative because they were medically inoperable or their tumors were either unresectable or would require extensive skull base surgery. The lesions studied include jugulare, vagale, and jugulotympanic tumors. The diagnosis was based either on prior surgical biopsy or on classic angiographic appearance in addition to other radiologic findings.

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Twenty-five tumors (24 patients) were felt to have adequate CT and/or MR studies for evaluation. A total of 44 contrast-enhanced CT scans and 29 MR scans were performed. Eighteen tumors (17 patients) underwent both pretreatment and posttreatment imaging which consisted of a combination of CT and MR examinations. One tumor was imaged only after treatment; six tumors had only pretreatment imaging studies. Of the 18 tumors with pre- and postimaging, six tumors had pre- and posttreatment MR scans. The remaining 12 tumors had a combination of CT and MR imaging before and after treatment.

A total of 37 imaging studies were performed after radiation therapy with some tumors undergoing multiple studies. These studies included 27 contrast-enhanced CT and 17 MR scans. All of the posttreatment MR scans except one were performed with intravenous paramagnetic contrast enhancement. The mean time interval from the completion of radiation therapy and the follow-up CT studies was 42.6 months (5–228 months). For MR, the mean interval was 32.7 months (1.5–131 months). For both CT and MR, the mean interval was 38.4 months.

All CT examinations were performed after the administration of intravenous contrast. The majority of CT scans were performed on a GE 9800 (General Electric, Milwaukee, WI) scanner with axial contiguous 1.5-mm axial sections through the temporal bone and contiguous 3.0-mm sections through the remainder of the region of interest below the skull base and into the neck. MR studies were performed on either a 1.0-T (Siemens, Iselin, NJ) or a 1.5-T (General Electric, Milwaukee) scanner. One study was performed on a 0.15-T scanner (Technicare, Cleveland, OH). Standard T1-weighted (600/20 [repetition time/echo time]) and T2-weighted (2500/20,90) sequences were performed on all MR studies except one posttreatment study in which the T2-weighted images were acquired using fast spin-echo pulse sequence (6000/102) which is commercially available on the 1.5-T system. Two MR studies were performed without gadolinium enhancement. All other MR examinations were performed before and after the intravenous administration of gadopentetate dimeglumine (0.2 ml/kg).

All patients were treated with a standardized protocol used at our institution for paragangliomas. This consisted of a dose of 4500 cGy administered in 25 fractions over a 5-week period. Local tumor control was defined by lack of progression of clinical symptoms and evidence of tumor shrinkage or stability on follow-up imaging studies. Clinical follow-up ranged from 1 to 21 years.

Pretreatment studies were evaluated for tumor size and enhancement pattern and the presence of bone erosion, intracranial extension, and flow voids. The T2 signal intensity with respect to cerebellar white matter was recorded for the MR studies. The posttreatment studies were evaluated in the same manner noting any changes from the pretreatment scans. Bone erosion was defined on CT as decreased mineralization and loss of the cortical margin adjacent to the tumor; it was not evaluated on MR studies. Size measurements were obtained by measuring the largest tumor dimension on the axial set of images and making a second measurement perpendicular to the first on the same image. Percent size reduction was calculated by multiplying these two dimensions before and after treatment and dividing the posttreatment value by the pretreatment value and multiplying by 100. The length of the lesion was also measured but was not used in the calculation of the percent reduction in size. Statistical analyses were performed using the Fischer Exact Test.

Results

The study included a total of 24 patients with 25 tumors, one patient having bilateral glomus jugulotympanic tumors. Nineteen patients were female (76%) and five were male (24%). The average age at presentation for radiation therapy was 58.3 years (range 28–87). Three patients had a history of multiple tumors (12%). One of these patients had bilateral glomus tumors and both of these were included in this study. The other two patients had had prior surgical resection of one tumor with the remaining tumor being included in this study.

The tumors were composed of paragangliomas of the head and neck and consisted of 15 jugulare (60%), five vagale (20%), and 5 jugulotympanic (20%) lesions.

Presenting clinical symptoms were varied and included those often associated with glomus tumors depending on their location. The symptoms included decreased hearing, tinnitus, dysphagia, pulsatile mass, hoarseness, headaches, dysarthria, bleeding, visual disturbances, and facial numbness. Seventeen patients had symptomatic improvement; seven patients demonstrated no change in their presenting symptoms. Thirteen patients had specific cranial nerve abnormalities with seven patients showing symptomatic improvement after therapy. Complications after therapy consisted of xerostomia (10 patients) and otitis externa (one patient). One patient had a central nervous system syndrome characterized by somonolence 6 to 8 weeks after completion of radiation therapy which subsequently resolved. This patient did not have evidence of tumor progression on follow-up imaging studies. No patient died as a result of a tumor.

Eleven of the 18 tumors (61%) imaged both before and after treatment demonstrated a reduction in size; the other seven showed no change. The average reduction in size was 23% (8%–45%). No tumors increased in size.

Twenty-one tumors had pretreatment CT imaging with 11 tumors undergoing both pre- and posttreatment CT imaging. Sixteen of these tumors were associated with bone destruction. All

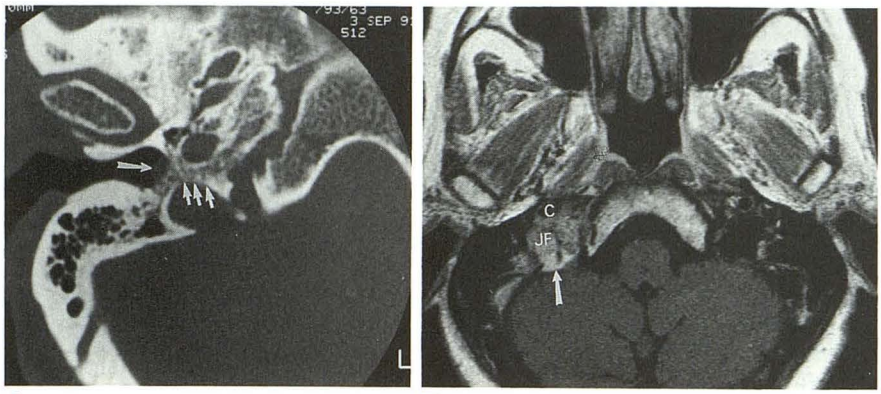

Fig. 1. *A*, Axial CT of a jugulotympanic tumor imaged with bone algorithm demonstrates osteopenia between the jugular fossa and the carotid canal with erosion of the cortical bone of the fossa (*small arrows*) associated with a mass protruding into the middle ear cavity (*large arrow*).

B, Corresponding axial T1-weighted MR demonstrates tumor (*arrow*) growing between the jugular fossa (*JF*) and the carotid canal (*C*) accounting for the osteopenia seen on CT in Fig 1A.

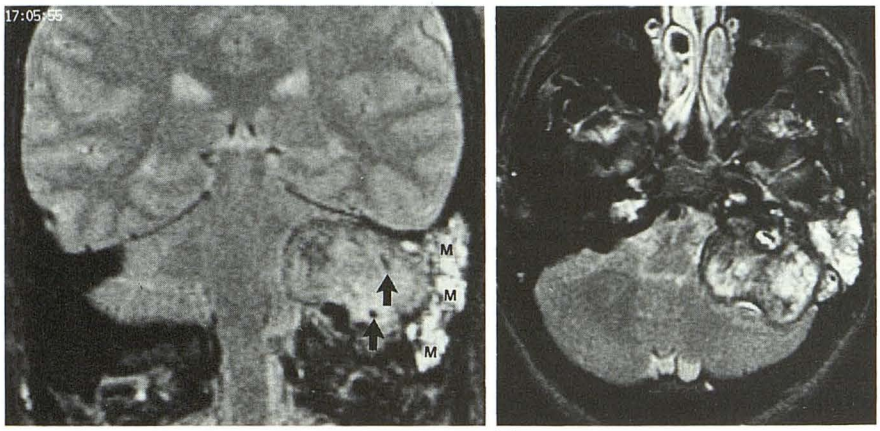

Fig. 2. T2-weighted images.

A, Coronal image of a jugulare tumor demonstrates a slightly heterogeneous lesion with internal flow voids (*arrows*). Note that increased signal in the mastoid air cells (*M*) appears distinct from that of tumor.

B, Axial image after radiation therapy demonstrates much more heterogeneous appearance of tumor manifested by patchy areas of increased and decreased signal which were not present before therapy.

of the patients with glomus jugulare tumors and three of five patients with jugulotympanic tumors demonstrated bone erosion (Fig 1). Eight of these 16 tumors with bone destruction underwent a posttreatment CT scan. Only one of these eight tumors demonstrated evidence of bone healing after treatment as manifested by remineralization and sclerosis in the previous area of bone destruction. Bone healing was first present on a study performed 14 months after the completion of radiation therapy and was not present on the initial follow-up CT performed 5 months after the completion of therapy. None of these eight patients had clinical signs of recurrent disease. No tumor demonstrated progressive bone destruction after radiation treatment. One tumor developed amorphous calcification and zones of gross necrosis in the tumor bed after treatment which was demonstrated on CT performed 42 months after the completion of therapy.

Twelve tumors were imaged with MR before radiation treatment. The T2 signal was variable. Five tumors were homogeneously (excluding areas of obvious flow voids) isointense to cerebellar white matter; six tumors were homogeneously hyperintense to white matter. T2-weighted images were unavailable in one patient. No tumors were hypointense to white matter before treatment.

Eleven tumors underwent posttreatment MR with either CT and/or MR evaluation before treatment. The posttreatment T2 signal when compared with the cerebellum was variable. Three tumors had signal greater than the cerebellar white matter, two tumors had signal which was equal to, and four tumors had signal which was homogeneously decreased. Two tumors demonstrated heterogeneous T2 signal with areas of both increased and decreased signal.

Six of the 11 tumors described above had undergone serial pre- and posttreatment MR imaging. Three tumors demonstrated no change in T2 signal. Three tumors had altered T2 signal after radiation therapy. One tumor demonstrated patchy areas of increased and decreased T2 signal (Fig 2) and two tumors had decreased signal compared with the pretreatment study (Fig 3). In one tumor with diminished T2 signal after radia-

tion therapy, T2-weighted images were acquired using fast spin-echo. In this case, the initial 5-month follow-up study using conventional spin-echo demonstrated no change in T2 signal; the 14-month follow-up with the fast spin-echo demonstrated loss of T2 signal. The time intervals between the completion of radiation therapy and the MR findings in these six tumors are summarized in Table 1.

Fourteen of 17 tumors imaged with MR demonstrated flow voids. All tumors with at least one of the three dimensions measured greater than or equal to 25 mm demonstrated flow voids. Only one of four tumors with all dimensions less than 25 mm demonstrated flow voids ($P < .006$). Four of the six tumors that had both pre- and posttreatment MR imaging demonstrated a decrease in the number of flow voids after treatment (Figs 3 and 4).

All tumors demonstrated marked enhancement after intravenous contrast administration before treatment. Of the six tumors with pre- and posttreatment MR imaging, three demonstrated decreased patchy contrast enhancement after radiation therapy compared with a homogeneous enhancement pattern before treatment (Fig 4). One tumor did not have a gadolinium-enhanced study before initiation of treatment. The alterations in the visualization of flow voids, contrast enhancement, and change in size of tumor with respect to the time interval between the follow-up study and completion of treatment are summarized in Table 1.

Discussion

Paragangliomas are slow-growing tumors arising from glomus bodies, which are considered a part of the chemoreceptor system. Glomus tissue has been found in various regions in the head and neck. Common sites include the adventitia of the jugular bulb beneath the floor of the middle ear, along the course (2) or within the bony walls (3) surrounding the tympanic branch of the glossopharyngeal nerve (Jacobsen nerve) which extends to the cochlear promontory and the auricular branch of the vagus nerve (Arnold nerve) (2). This tissue is identical to that found in the ganglion nodosum of the vagus nerve found in the neck and the glomus carotidicum (carotid body) situated at the bifurcation (4). The various glomus tumors are similar histologically and named according to their site of origin.

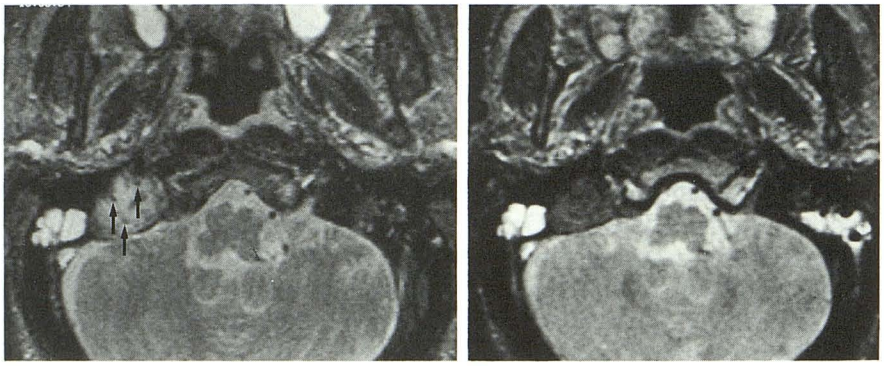

Fig. 3. Axial T2-weighted images.
A, Before radiation therapy, the jugulare tumor is hyperintense to cerebellar white matter, except areas that represent flow voids (*arrows*).
B, After radiation therapy, the tumor demonstrates marked loss of T2 signal and decreased flow voids.

TABLE 1: Comparison of pretreatment and posttreatment MR findings in irradiated paragangliomas

Patient	Months from Completion of Radiation Therapy to Follow-up MR	Changes after Radiation Therapy			
		Enhancement	Flow Voids	T2 Signal	% Decrease in Size
1	4	No change	No change	No change	0
	14	Decreased	Decreased	Decreased*	0
2	9	No change	No change	No change	19
3	12	Decreased	Decreased	Heterogeneous	0
4	69	Pretreatment without Gd	Decreased	No change	34
5	1.5	No change	No change	No change	17
6	14	Decreased	Decreased	Decreased	10

* Second follow-up study performed using T2-weighted fast spin-echo imaging.

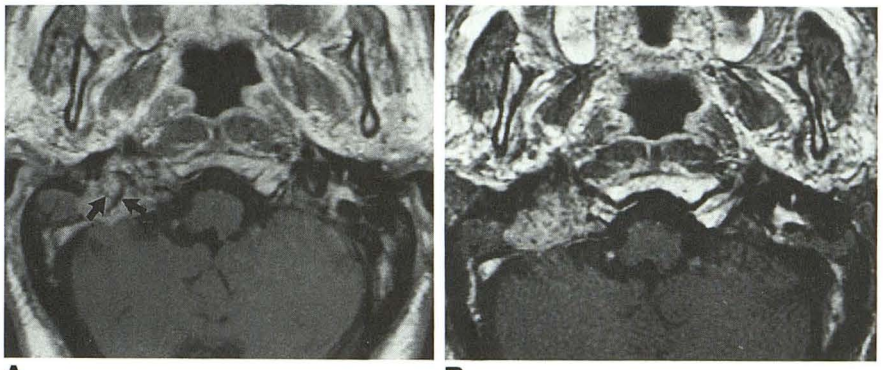

Fig. 4. Enhanced axial T1-weighted images.

A, Pretreatment image of a jugulare tumor demonstrates homogeneous lesion with obvious flow voids (*arrows*).

B, After radiation therapy, the tumor demonstrates a more heterogeneous enhancement pattern with a marked reduction in the size and number of flow voids.

Radiation therapy has proved to be a viable alternative for treatment of paragangliomas and was originally used for those lesions with bony extension which would prohibit full surgical exposure and preclude complete resection (5). Currently it is offered as an option to patients who do not wish to undergo surgery and/or accept the deficits associated with possible sacrifice of adjacent cranial nerves.

All of the tumors treated with radiotherapy demonstrated persistence of tumor mass. Although 61% of the tumors demonstrated some degree of shrinkage (8% to 45%), no tumor completely resolved. Seventy-one percent of the patients demonstrated improvement of their initial clinical symptoms. None of the patients demonstrated clinical or radiographic evidence of progression of disease. Consequently, the presence of the tumor does not indicate active tumor and one, as a rule, observes substantial residual masses in successfully treated patients (5).

All patients with glomus jugulare tumors demonstrated bone erosion. Three of five patients with glomus jugulotympanic tumors demonstrated bone erosion. The tumor in the latter lesions appeared to extend into the inferior tympanic canaliculus or along branches of cranial nerves IX and X. Even though all tumors were controlled, only one demonstrated evidence of bone healing. The presence of bone remineralization is likely a reliable sign of local control; however, the presence of persistent bone demineralization and erosion without progression does not indicate treatment failure and is to be expected.

High-field-strength MR imaging using high resolution techniques demonstrated relatively isointense masses on T1-weighted images that exhibited homogeneous contrast enhancement on pretreatment examinations. We found the use of gadolinium beneficial for the evaluation of glomus tumors. Gadolinium enhancement helped determine the vascularity of the tumors and improved the visualization of flow voids. The differential enhancement of the mass with respect to the surrounding uninvolved tissues helped delineate the full extent of the mass. Precontrast T1-weighted images may be beneficial for determination of marrow involvement because postcontrast T1-weighted images can make separation between tumor and bone marrow difficult (1). Gadolinium was helpful in the evaluation of posttreatment imaging because several tumors demonstrated heterogeneously decreased enhancement compared with the pretreatment studies.

The T2 signal characteristics were variable in both irradiated and nonirradiated tumors. No correlation with length of time between treatment and T2 signal intensity on follow-up MR could be established. T2 signal intensity less than cerebellar white matter was seen only in postirradiated patients and could represent fibrosis caused by radiation therapy. The variation in signal intensity on T2-weighted images after radiation therapy could represent a combination of necrosis, edema, inflammation, hemosiderin, and fibrosis, which had been previously described in histologic sections of previously irradiated paragangliomas (6). Consequently, signal greater than white matter on T2-weighted images is likely not a reliable sign of tumor control because it may be seen in lesions that have not been treated. However, loss of T2 signal after treatment appears to be a result of therapy and is suggestive of tumor control.

Flow voids were mostly observed in tumors with at least one dimension greater than or equal to 25 mm. Only one tumor that was less than 25 mm in all dimensions demonstrated flow voids. The statistical analysis confirms a significant difference in the presence or absence of flow voids based on tumor size ($P < .006$). Thus, in small tumors (less than 2.5 cm in greatest dimension),

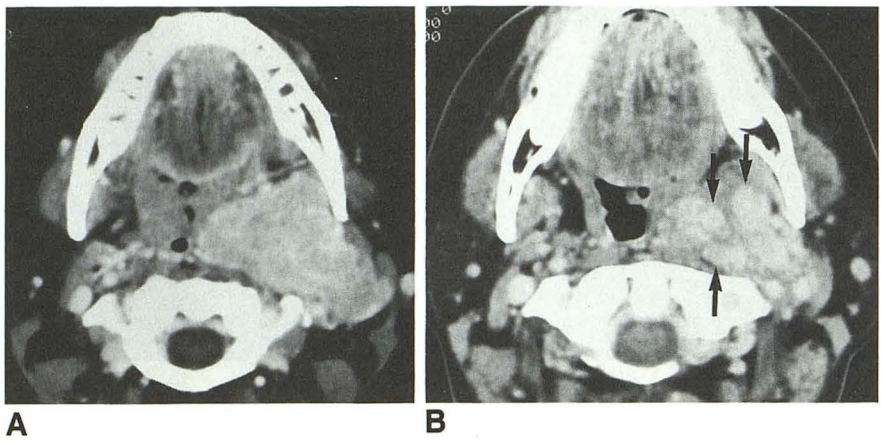

Fig. 5. Axial enhanced CT images.

A, Homogeneously enhancing glomus vagale tumor before treatment.

B, After radiation therapy, the tumor has decreased in size and has developed coalescent areas of enhancement (*arrows*) which were not seen on the pretreatment study. These areas may represent large vascular spaces or regions of differentially enhancing tumor.

the diagnosis of paraganglioma cannot be excluded based on the absence of flow voids. However, we feel the presence of bone erosion associated with lesions of the jugular fossa is suggestive of a glomus tumor and helps to exclude other neoplasms that occur in this region such as schwanoma. Diagnosis of a small paraganglioma short of biopsy, therefore, requires angiographic proof and evidence of aggressive bone erosion on CT.

The tumors in our study were homogeneous except for the presence of flow voids. The "salt and pepper" pattern originally described for paragangliomas likely represents in part the inability of low-field strength units available at that time to resolve flow voids from an otherwise homogeneous tumor (7).

As expected, the results from Table 1 demonstrate that decreased flow voids resulting from radiation therapy are associated with decreased overall tumor enhancement. The presence of decreasing flow voids and patchy enhancement observed after treatment correlates with previous reports of histologic and angiographic findings seen in irradiated tumors. Histologically, after radiation therapy one sees myxoid degeneration of vessel walls with intimal proliferation, partial obliteration, revascularization, and thrombosis (6). Angiographically, one observes a decrease in tumor blush and feeding vessel size along with decreased arteriovenous shunting (8). Thus, decreased flow voids and decreased enhancement after radiation therapy appear to reflect the regressive changes noted in those previous histopathologic studies and may be considered supportive evidence of tumor response in the absence of tumor shrinkage.

In one tumor with pre- and posttreatment MR imaging, the findings of decreased flow voids, diminished enhancement, and reduced T2 signal compared with pretreatment imaging were present on a study 14 months after treatment and were not present on an initial 4 month follow-up study (Table 1). In fact, all tumors with posttreatment MR imaging that demonstrated diminutive flow voids, heterogeneous enhancement, or reduced T2 signal were imaged at least 12 months after the completion of treatment. This suggests that MR findings commonly associated with irradiation may not be seen on early follow-up studies (less than 1 year). These findings, however, may become evident on subsequent studies performed at least 1 year after the completion of therapy. Consequently, the lack of these findings in the early posttreatment period does not indicate treatment failure: these changes may become apparent on follow-up studies.

Several tumors demonstrated moderate to large vascular pools after radiation treatment (Fig 5). These pools could represent dilatation of vessels as a result of treatment. However, this appearance could also represent a variation in tumor enhancement caused by a change in the time between contrast administration and image acquisition between comparable studies (9).

Successfully irradiated paragangliomas demonstrate a variety of CT and MR findings. All tumors demonstrated a residual mass after radiation therapy and this finding is to be expected. The presence of heterogeneous enhancement, diminished flow voids and decreased T2 signal after radiation therapy occur as a result of therapy and are likely indicative of local control in the presence of a residual mass. However, these findings may not be present if the tumor is imaged within 1 year after the completion of therapy. After successful treatment, bone healing is rarely seen, but when present may be a sign of local

control. The finding of persistent bone erosion and demineralization after radiation therapy without progression compared with the pretreatment study is commonly seen in successfully controlled tumors. Consequently, this finding is not indicative of treatment failure and surgical resection of residual masses is not indicated in the presence of a stable neurological examination.

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