MR Imaging of the Intraparotid Facial Nerve: Normal Anatomy and Pathology

Louis M. Teresi, Elliot Kolin, Robert B. Lufkin and William N. Hanafee

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Louis M. Teresi[1]
Elliot Kolin[2]
Robert B. Lufkin[1]
William N. Hanafee[1]

Three normal volunteers, 58 normal patients, and three patients with parotid tumors were studied with a 0.3 T permanent-magnet imaging system to directly image the intraparotid facial nerve. On T1-weighted images the nerve appeared as a curvilinear structure of relatively low signal intensity within the fatty, high-signal parotid parenchyma. Its major divisions and branches could be imaged only with specially angled axial scan planes. To verify our observations MR imaging was compared with whole-organ cryomicrotome sections cut at the same angles. Normal variations in the appearance of the nerve and pitfalls in its visualization are discussed. Three cases of parotid tumors, with surgical confirmation of the relationship of the facial nerve to the tumor, are presented. MR is the only imaging technique capable of direct imaging of the facial nerve in the parotid bed: it may assist materially in the surgical management of tumors of the parotid gland.

The arrangement of the facial nerve within the parotid gland is of major surgical concern. Tumors that lie superficial to the facial nerve are generally treated by superficial parotidectomy. If a tumor is deep to the facial nerve, the management is changed from superficial to total parotidectomy. In each case the surgeon must identify the branches of the facial nerve in order to preserve its function and to develop a plane of dissection [1, 2].

Although the nerve itself is not seen on CT scans, CT sialography can delineate the same anatomic landmarks that are used to isolate the nerve at surgery [3, 4]. The variability of these landmarks and the difficulty in seeing them at different levels, however, limits the usefulness of this method [5]. MR imaging with surface receiver coils produces images with contrast resolution superior to CT and with comparable spatial resolution. We have recently used MR to directly image the intraparotid facial nerve.

Materials and Methods

Technique

All scans were performed on a 0.3 T permanent-magnet imaging system (Fonar B-3000) using either a 14-cm surface coil or a 24-cm-bore head receiver coil. Images were acquired using a multislice 2DFT rapid spin-echo (SE) technique with an echo time (TE) of 28 msec and a repetition time (TR) of 500 msec. Usually, four excitations in a 256 × 256 matrix for each image were used with a section thickness of 4 mm and 7-mm separations from center-to-center slice. Other images were similarly acquired on a 512 × 512 matrix. This high-resolution technique decreased the pixel size from 0.75 × 0.75 mm^2 to 0.5 × 0.5 mm^2. Seven simultaneous sections were obtained in each sequence with a total imaging time of 8.5 min (256 × 256 matrix) or 12.8 min (512 × 512 matrix).

Three normal volunteers were scanned to determine the optimal scanning protocol for visualizing the trunk and major branches of the facial nerve. Multislice

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[1]Department of Radiology, UCLA Medical Center, BL-428, Los Angeles, CA 90024. Address reprint requests to L. M. Teresi.

[2]Department of Radiological Sciences, Mount Sinai School of Medicine, New York, NY 10211.

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scanning was performed in sagittal, coronal, and axial planes so that the relation of normal structures could be verified in various projections. Initial images were frequently used as "scouts" so that precise scan-plane localization could be performed to identify small anatomic structures. For each plane a second sequence was conducted when needed to provide slightly overlapping sections and to demonstrate the planes of tissue between levels.

Several angled axial planes were studied to determine the best view of the main divisions of the facial nerve. First, a seven-slice sagittal "scout" scan was obtained through the parotid gland, including the orbit and temporal bone. Using the axial plane formed by drawing a line through the inferior margin of the anterior portion of the orbit and the external auditory meatus as the reference (0°) and the external auditory meatus as the fulcrum, axial scans angled from 30° (cephalad) to −60° (caudal) were studied in 5° intervals (see Figs. 3 and 4). Those axial scanning angles that best showed the nerve were compared with whole-organ cryomicrotome sections cut at the same angle.

Whole-organ sections were obtained from two cadavers using a cryomicrotome freezing-sectioning technique previously described by Rauschning et al. [6]. Cadaver specimens were first prepared by arterial injection of pigmented barium compound to permit identification of arteries and veins. A block of the head including the temporal bone and parotid gland was frozen to −20° C. Using the cryomicrotome (LKB Instruments), these nondecalcified specimens were shaved at 10-μm increments and photographed every 0.5 mm. Photographs of representative gross sections were then compared with the respective normal MR sections.

Material

In the past 1½ years 58 patients with normal parotid glands were scanned in sagittal, axial, and coronal sections. Most of the normal examinations were conducted for temporal-bone imaging as part of a work-up for hearing loss or tinnitus. We reviewed these 58 scans, noting the angle of the axial scans relative to the orbital-meatal line. Axial scans that were incidentally taken at the angle we determined was best for imaging the major divisions of the nerve were reviewed, and variations in the direction and configuration of the facial nerve were noted. Although the subject of a separate report, three illustrative cases of parotid tumors, with surgical confirmation of the relationship of the nerve to the tumor, are presented.

Results

Normal Anatomy

The facial nerve enters the parotid gland immediately upon leaving the stylomastoid foramen. It passes in front of the posterior belly of the digastric muscle and lateral to the styloid process, the external carotid artery, and the posterior facial vein. When the nerve reaches the posterior border of the ramus of the mandible, it divides into its two main, temporofacial and cervicofacial, branches. The main branches anastomose as the pes anserinus and then further divide into temporal, zygomatic, buccal, mandibular, and cervical branches (Fig. 1). Rami of these branches anastomose variably within the substance of the parotid. Within the parotid the nerve and its branches run in a single plane, following an arciform course that is concave upward and medially. This plane separates the superficial and deep lobes of the parotid [5, 7].

From its exit through the stylomastoid foramen, the main trunk of the facial nerve is best seen in the sagittal plane. On T1-weighted images the nerve appears as an intermediate-intensity structure within the high-signal, relatively fatty, glandular substance of the parotid (Fig. 2). On select sagittal images the bifurcation of the main nerve trunk into the cervicofacial and temporofacial branches can be seen. Occasionally, a bright area of fat is seen enveloping the nerve in the stylomastoid foramen and the descending facial canal.

The major branches of the nerve are best visualized with selected angled axial images. Using a scanning plane angled −35° (plus or minus 5°) caudal to the orbital-meatal line, the main trunk of the nerve, its cervicofacial division, and its more peripheral branches could be seen through the length of the parotid gland (Fig. 3). On most scans only segments of the nerve could be identified on individual slices, requiring two to three slices to visualize the entire intraparotid portion of the nerve. Not infrequently, however, the entire nerve was visualized on a single slice. By angling 15° (plus or minus 5°) cephalad to the orbital-meatal line, the temporofacial division and its branches could be seen (Fig. 4).

On caudally angled axial scans the nerve takes a characteristic course from the stylomastoid foramen through the parotid gland. After exiting the stylomastoid foramen it courses inferiorly and slightly laterally for 3–5 mm, then turns more acutely laterally to pass above and in front of the posterior belly of the digastric muscle. It then turns anteriorly, creating a smooth, medially concave arch that nearly bisects the parotid gland. The nerve thus takes the form of an intermediate-intensity, gently shaped "S" structure within the

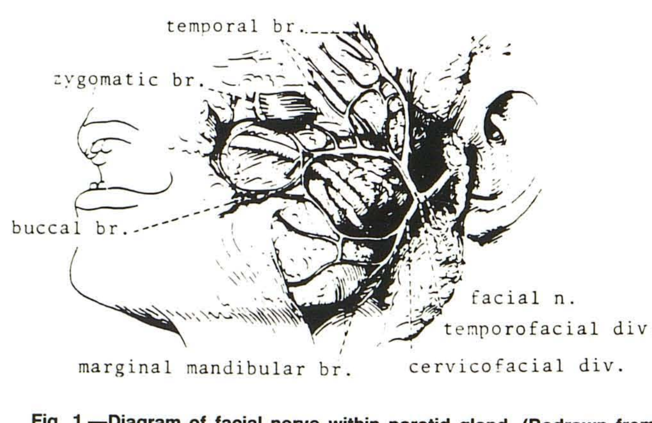
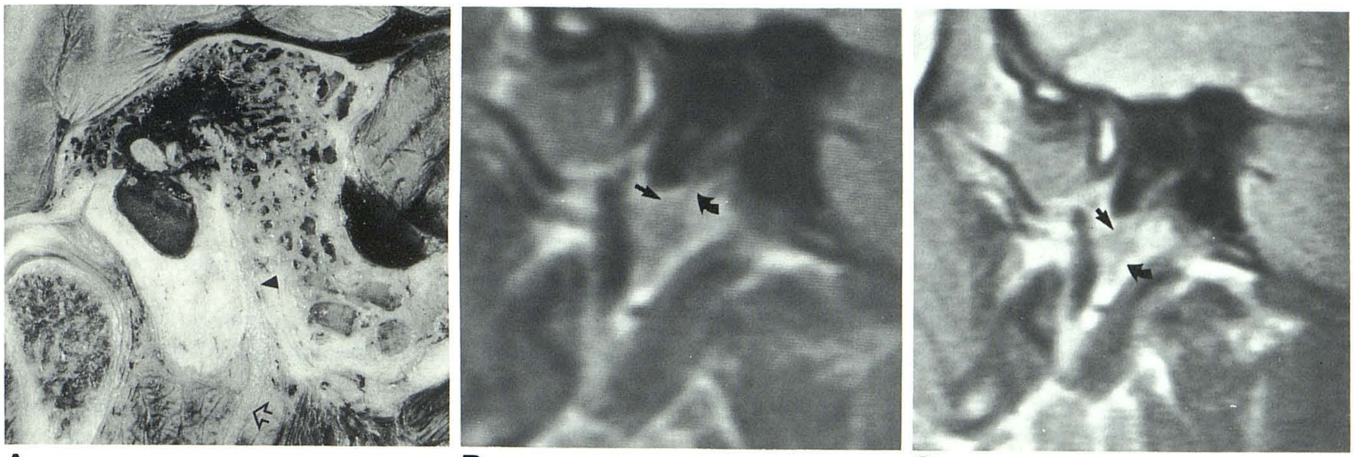


Fig. 1.—Diagram of facial nerve within parotid gland. (Redrawn from [1].)



A B C

Fig. 2.—Sagittal sections of temporal bone and parotid gland.

***A*, Cadaver section shows facial nerve (*arrowhead*) in descending facial canal and main trunk of nerve (*open arrow*) exiting stylomastoid foramen.**

***B*, Sagittal image using SE technique, 28 msec TE and 500 msec TR, shows main trunk of facial nerve (*curved arrow*) exiting stylomastoid foramen. Upper, temporofacial division (*straight arrow*) of nerve is also seen.**

***C*, Sagittal slice 2 mm lateral to that in *B* shows to better advantage the bifurcation of the main trunk into its temporofacial (*straight arrow*) and cervicofacial (*curved arrow*) divisions. Precise, calculated slice placement is frequently necessary to visualize the nerve.**

higher-intensity parotid gland. On cephalad-angled scans the main trunk is imaged in cross section rather than longitudinally; thus the proximal portion of the "S" is not well seen on these scans. The medially concave distal arch, respresenting the temporofacial division in this case, is well depicted.

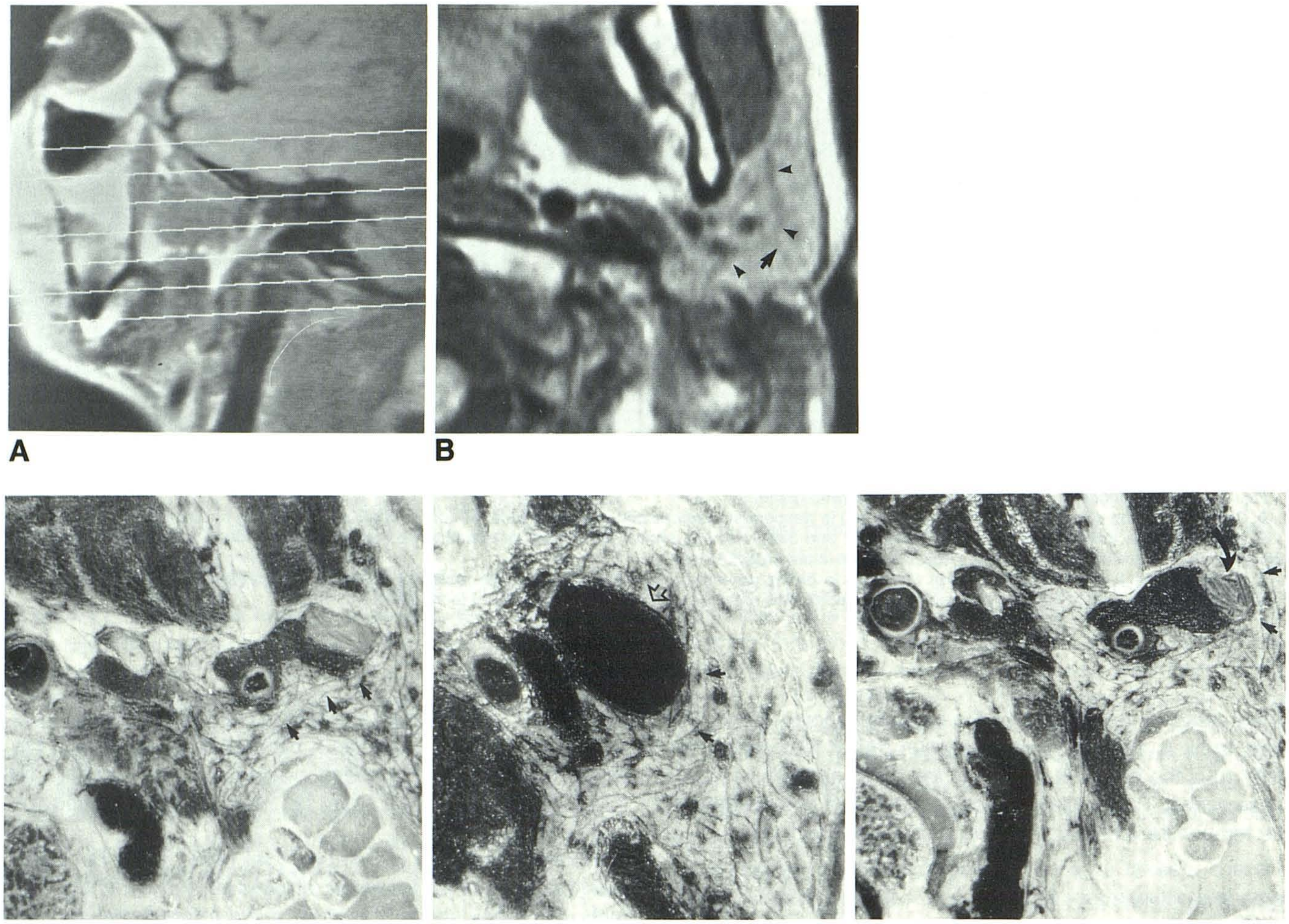
Normal Variations and Pitfalls

Eight of 58 normal parotid scans obtained in the past 1½ years incidentally included axial images taken −30° to −40° caudal to the orbital-meatal line. Similarly, six of the 58 scans included images taken 10–20° cephalad of the orbital-meatal line. Of these 14 scans, nine showed the entire intraparotid facial nerve while two caudally angled scans showed only a portion of the cervicofacial division. Three caudally angled scans showed no part of the nerve. Most scans (six of nine cases) showed sections of the nerve on individual slices, requiring two to three 4-mm-thick slices to image the entire nerve. Not infrequently (three of nine cases), the entire nerve was seen on a single slice. Thus, in 11 of 14 cases (79%) using the appropriately angled axial scanning planes, major portions of the nerve could be visualized.

In these 11 normal patients several variations in the normal appearance and course of the nerve were observed. Although the nerve is most frequently visualized as a smooth-surfaced, "S"-shaped structure, occasionally the more proximal portion of the nerve takes a straighter, more lateral course from the stylomastoid foramen, or the distal medially concave bend of the nerve takes a more acute turn around the ramus of the mandible. Similarly, the most distal portion of the nerve may appear straight rather than curvilinear. The nerve occasionally has small bulges on its surface, probably depicting points of branching or anastamoses, or small penetrating veins abutting its surface (Fig. 3). Occasionally (three of 11 cases), the smaller branches of the nerve can be seen, especially the postauricular branch coursing posterior to the mastoid tip (Fig. 3B). Abrupt "kinks" may be seen anywhere along the course of the nerve.

Within the parotid gland the facial nerve must be distinguished from other anatomic structures and scanning artifacts. On many scans branches of the retromandibular vein can be seen penetrating the substance of the parotid and coursing in a medially concave arch, not unlike the facial nerve (Fig. 5A). These penetrating branches can be distinguished from the nerve in the following respects: (1) the veins are always medial to the normal, midline position of the nerve (the nerve is frequently seen coursing laterally and parallel to the branches of the vein); (2) they are of slightly lower signal intensity than the nerve secondary to flowing blood; and (3) they can be seen uniting with the retromandibular vein. The −35° caudally angled scan is particularly useful as this angle shows the main trunk of the nerve exiting the stylomastoid foramen. One can be assured that a structure in the distal substance of the parotid is the facial nerve if it can be traced back to the stylomastoid foramen. Similarly, small branches of the internal maxillary artery may simulate the appearance of the nerve on sagittal scans. Identifying the nerve exiting the stylomastoid foramen eliminates any confusion.

Truncation artifacts may also simulate the nerve by producing a low signal line adjacent to borders or tissue discontinuities. The truncation of the infinite Fourier series necessary to encode edges to the 128 to 512 terms produces the artifact [8]. In axial images of the parotid, the tissue discontinuity formed between the very high-signal superficial fascia and the lower-intensity parotid parenchyma allows for the formation of the artifact in the frequency encoding X axis (Fig. 5B).



A B

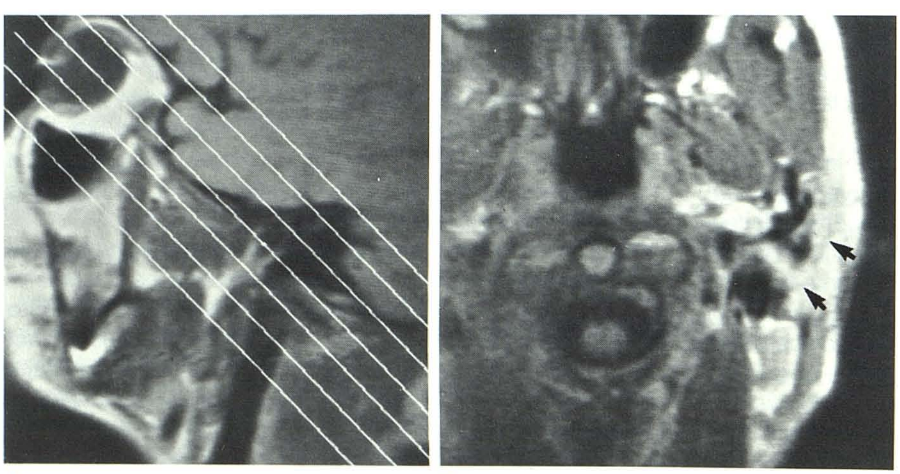
C D E

Fig. 3.—Caudally angled axial scan.

A, Scout image shows positioning of slices −35° (caudal) to orbital-meatal line.

B, Resulting 4-mm-thick slice shows entire length of curvilinear intraparotid facial nerve (*arrowheads*). Postauricular branch (*arrow*) of nerve is occasionally seen.

C–E, Corresponding cadaver sections cut at same angle show sections of facial nerve (*arrows*) coursing lateral to retromandibular vein (*open arrowhead*). This projection shows to best advantage the main trunk and cervicofacial division. Parotid duct (*curved arrow*) is sometimes not seen on T1-weighted images.



A B

Fig. 4—Cephalad-angled axial scan.

A, Scout image shows positioning of slices 15° (cephalad) to orbital meatal line.

B, Resulting image shows temporofacial division (*arrows*) of nerve. Main trunk is not well visualized in this projection.

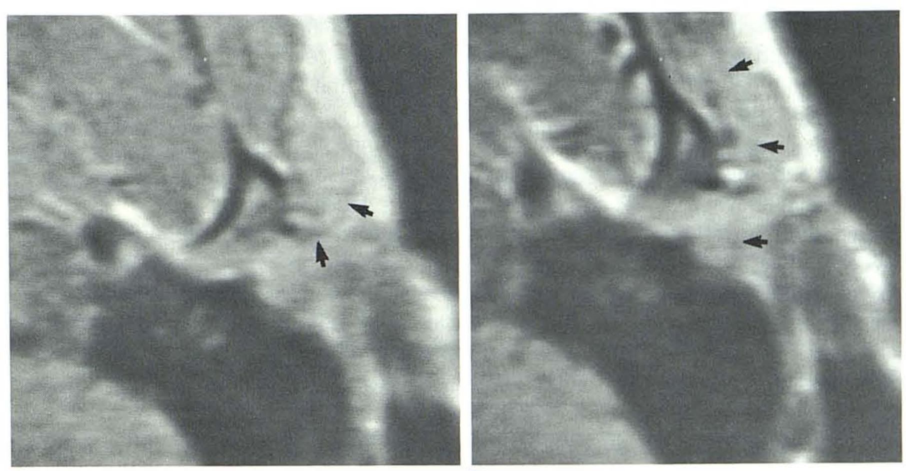
Unlike the facial nerve, these lines are absolutely parallel to the outermost edge of the parotid and continue through the parotid into muscles of the face. Several parallel artifactual lines may be seen at regular intervals through the gland. Again, in doubtful situations, the nerve may be traced from the stylomastoid foramen.

Parotid Tumors: Case Reports

Case 1: A 43-year-old man presented with a 3-month history of a lump on the right side of his jaw. An MR scan revealed a high-signal mass in the superficial lobe of the parotid gland (Fig. 6A). The main trunk and a segment of the cervicofacial division of the facial nerve were seen deep to the tumor. The postauricular branch of the nerve was seen interfacing with the superior aspect of the mass (Fig. 6B). At surgery, the facial nerve was found deep to the tumor, confirming the MR scan. The postauricular branch, although uninvolved by the benign tumor, was directly abutting it. The surgeons proceeded with a superficial parotidectomy, confirming the MR observations. Pathology showed the mass to be a lipoma.

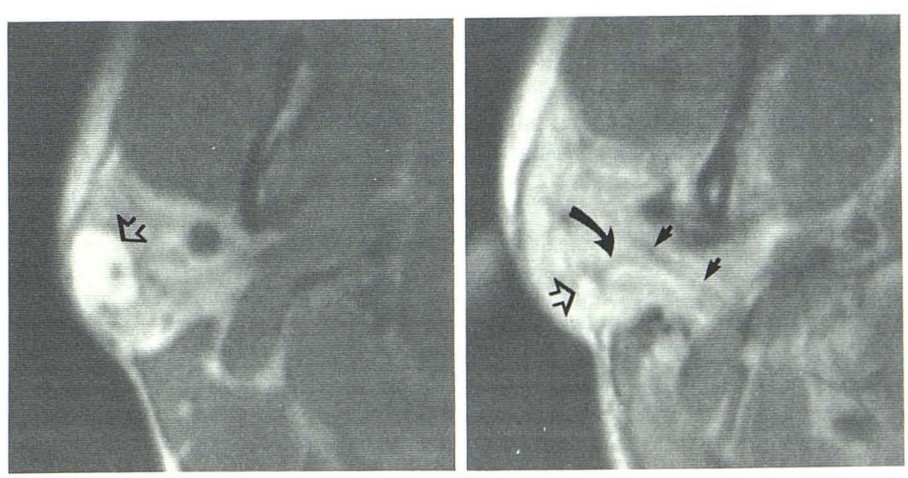
Case 2: A 39-year-old woman presented with a 6-week history of a progressively enlarging mass on the left side of her face. An MR scan showed a large, intermediate-intensity lesion in the deep lobe of the parotid gland. The cervicofacial branch of the facial nerve was observed to course laterally to the mass (Fig. 7). The surgeons proceeded with a total parotidectomy, where the facial nerve was found as described by the MR study. Pathology revealed a pleomorphic adenoma.

Case 3: A 54-year-old man presented with a 9-week history of a progressively enlarging mass on the right side of his jaw. An MR scan revealed a large, intermediate- to low-signal lesion in the deep lobe of the parotid. The cervicofacial division of the facial nerve was seen displaced laterally (Fig. 8). During total parotidectomy, the facial nerve was dissected in the same plane described by the MR study. It was uninvolved by what pathology showed to be a cystic pleomorphic adenoma.



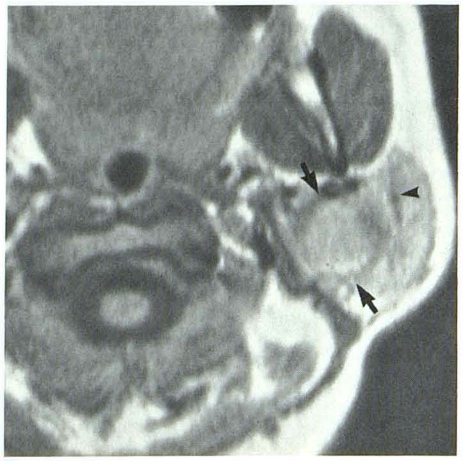
A B

Fig. 5.—Pitfalls.
***A*, Branch (*arrows*) of retromandibular vein simulating medial-concave arch of facial nerve.**
***B*, Truncation artifacts (*arrows*) simulating facial nerve.**



A B

Fig. 6.—Case 1.
***A*, Lipoma (*open arrow*) of superficial lobe.**
***B*, Cut 7 mm superior to *A* shows facial nerve (*straight arrows*) coursing superomedially to tumor. Postauricular branch (*curved arrow*) of nerve abuts superior aspect of tumor (*open arrow*).**



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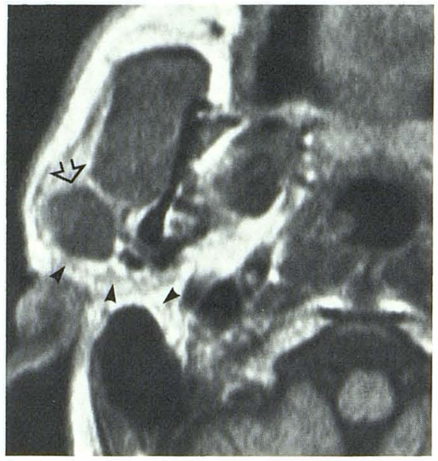

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Fig. 7.—Case 2. Pleomorphic adenoma (*arrows*) in deep lobe of parotid. Facial nerve (*arrowhead*) is seen lateral to mass.

Fig. 8.—Case 3. Facial nerve (*arrowheads*) displaced directly laterally by a large, cystic pleomorphic adenoma (*open arrow*) of the deep lobe.

Discussion

The relationship of parotid tumors to the facial nerve, which courses through and divides within the parotid gland, is of surgical significance. Determining the relationship of parotid-gland tumors to the facial nerve is of value in planning the surgical approach. Malignant tumors that are in close relation to the facial nerve may require excision of part of the facial nerve trunk and subsequent microsurgical repair [1, 2]. Access for large, deep lesions may need to be improved by division and reflection of the ramus of the mandible [1].

We have shown that MR can directly image the facial nerve within the substance of the parotid. Axial scans, angled appropriately to the orbital-meatal line, were best suited for imaging the main trunk and major divisions of the nerve. Scans angled −30° to −40° caudal to the orbital-meatal line showed the trunk, cervicofacial division, and its distal branches through the entire substance of the parotid, often on a single slice. The nerve had a variable, yet characteristic "S"-shaped appearance within the parotid on these scans. Similarly, scans angled 10–20° cephalad best showed the temporofacial branch and its major divisions; however, it did not show the trunk. The caudal scanning angle was the most useful, as the nerve could be seen exiting the stylomastoid foramen; therefore, it could be reliably distinguished from branches of the retromandibular vein and from truncation artifacts simulating the appearance of the nerve.

In patients with tumors of the parotid, the relationship of the tumor to the nerve was consistently visualized on angled axial scans. Small mass lesions were easily seen to be superficial or deep to the facial nerve. When the mass significantly distorted the normal parotid architecture, making it difficult to determine whether a tumor had originated in the superficial or deep lobe, MR showed the facial nerve displaced by the tumor. Thus, the site of origin could be inferred and the relationship of the displaced nerve to the tumor determined, which greatly assisted surgical planning. MR is the first imaging technique to allow direct visualization of the intraparotid facial nerve, and it may assist materially in the surgical management of tumors of the parotid gland.

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