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Application of Surface Coils to MR Anatomy of the Larynx

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The magnetic resonance (MR) scans of 10 patients with normal larynges were compared with cryomicrosections of two injected cadaver specimens. The MR images were obtained with a solenoid surface coil and high-resolution techinque that provided images 4 mm thick displayed on a 256 × 256 matrix. The improved signal-to-noise ratio of the surface coil allowed a detailed study of normal anatomy in the axial, coronal, and sagittal planes.

The structures of the neck are particularly difficult to image by magnetic resonance (MR). Head coils will not cover the middle and inferior regions of the neck because the shoulders interfere with positioning. Body coils are inefficient because of the poor coupling between the coil and the small size of the region of interest [1–3]. Surface coils have been shown to fill the gap between large-diameter receiving coils and small anatomic sites [4, 5]. In a permanent magnet with a vertical main magnetic field, solenoidal surface coils can be used to good advantage to image the intricate laryngeal structures. Two-dimensional multislice acquisitions permit rapid demonstration of the larynx in axial, coronal, and sagittal projections.

Subjects and Methods

Ten normal larynx examinations were performed using a flexible surface coil on a 0.3 T permanent-magnet imaging system (Fonar B-3000). The vertical orientation of the axis of the main magnetic field permits a solenoidal surface coil to be wrapped around segments of anatomy in the long axis of the body. This is in contrast to the horizontal axis of the main magnetic field of most systems, which prevents the use of solenoid coils in this orientation, that is, the axis of the solenoid coil must be orthogonal to the axis of the main magnetic field. Most of the examinations were conducted for testing of the coil or spinal cord imaging. A number of examinations have been performed on patients with tumors of the larynx, but these are a subject of a separate report. Multislice scanning was conducted in the axial, coronal, and sagittal planes so that relation of normal structures could be verified in various projections.

When necessary, a single-slice technique was used for localization, with the image being obtained in 1 min, 51 sec. A rapid spin-echo (SE) technique was used for all of the scans, utilizing an echo time (TE) of 28 msec and a repetition time (TR) of 500 msec. Four averages in a 256 × 256 matrix for each image usually were used, and the section thickness was 4 mm, with 7 mm separations from center-to-center slice. Seven simultaneous sections were obtained in each sequence with a total imaging time of either 4.25 min (two averages) or 8½ min (four averages) per sequence. The high-resolution "zoom mode" required the longer scan time. This high-resolution technique decreased the pixel size from 1 × 1 mm to 0.75 × 0.75 mm. For the axial and coronal projections a second sequence was conducted when needed to provide slightly overlapping sections and demonstration of the planes of tissue between levels. The T1-weighted images were quite adequate because of the high degree of contrast that is present between loose areolar tissue, muscle, and vascular structures.

The MR scans were compared with whole organ sections obtained from two cadavers using a cryomicrotome freezing-sectioning technique previously described by Rauschning et

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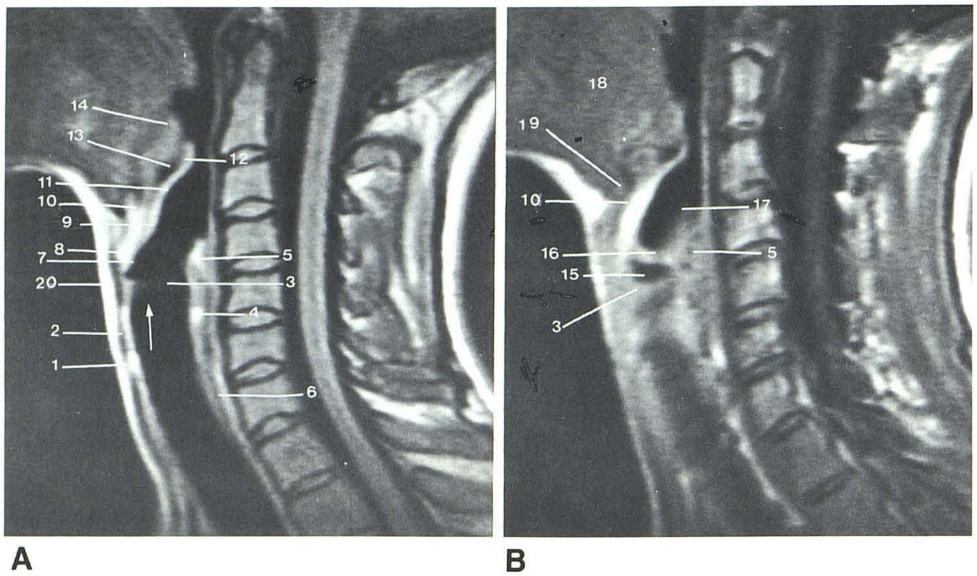


Fig. 1.—Normal larynx, sagittal projection. MR images using 28 msec TE, 500 msec TR, 4-mm-thick sections, 7 mm intervals, seven simultaneous sections, 8½ min scanning times. **A**, Midline sagittal section. Only anterior part of true vocal cord is in plane of section because posterior half of vocal cord is retracted laterally. Maximum airway is demonstrated because scan is obtained during quiet respiration. **B**, Through lateral part of true and false vocal cord but not into paralaryngeal space. Laryngeal ventricle still air-containing. 1 = tracheal ring; 2 = anterior ring of cricoid; 3 = true vocal cord; 4 = cricoid lamina; 5 = arytenoid cartilage; 6 = esophagus; 7 = thyroepiglottic ligament; 8 = symphysis of thyroid cartilages and thyroepiglottic ligament; 9 = petiole of epiglottis; 10 = preepiglottic space; 11 = body of epiglottis; 12 = free margin of epiglottis; 13 = vallecula; 14 = lingual tonsil; 15 = laryngeal ventricle; 16 = false vocal cord; 17 = beginning of aryepiglottic fold; 18 = tongue; 19 = hyoid bone; 20 = strap muscles.

TABLE 1: **Relations of Signal Level to Tissue Types at 28 msec TE and 500 msec TR**

Signal Level: Tissue Type
Bright:
Preepiglottic fat
Hyaline cartilage
Submucosal fascial planes
Thyroepiglottic ligament
High intermediate:
Lymphatic tissue
Paradoxically enhanced vessels
Glands of false vocal cords
Aryepiglottic folds
Low intermediate:
Intrinsic muscles (thyrocricoid especially)
Vocal ligament
Strap muscles
Fibrocartilage
Ligaments (hyoepiglottic)
Low:
Calcified cartilage
Airway
Blood vessels

al. [6, 7]. Cadaver specimens were first prepared by arterial injection of a pigmented barium compound to permit identification of arteries and veins. The larynx was excised and frozen to −20°C. Using the cryomicrotome (LKB Instruments), these nondecalcified specimens were shaved at 20 μm increments and photographed every millimeter. Photographs of representative gross sections were then compared with the respective normal MR sections in the living patient.

Results

Orientation in MR imaging of the larynx is not easy because some structures do not give sufficient signal for demonstration or there is a lack of contrast between adjacent areolar tissue and cartilaginous planes. Long TE (beyond 50 msec) and long TR (>1500 msec) will improve contrast but at a sacrifice of spatial resolution due to the decreased signal-to-noise (S/N) ratio of the long TE. Delicate intrinsic muscles are no longer visible. At times the amount of signal coming from cartilage may be quite varied, giving a spurious impression of multiple structures. This is especially troublesome in young patients when the posterior and inferior borders of the thyroid cartilage are beginning to calcify [8]. In older patients with densely calcified thyroid cartilages, the lack of signal permits easy identification of all borders of the cartilage. By far the best overall images were obtained with a 28 msec TE and 500 msec TR.

Sagittal Plane

The amount of signal coming from various anatomic structures on T1-weighted images can be clarified best by close scrutiny of sagittal scans (fig. 1). The bright signal from hyaline cartilage closely approximates that of subcutaneous fat and submucosal loose connective tissue. Calcified cartilage is of low signal intensity, much like cortical bone. The air is blackest of all, giving no signal. Cartilages that have a medullary cavity, such as the cricoid lamina, may give bright signal greater than that of hyaline cartilage. Fibroelastic cartilage such as the epiglottis is of intermediate range, much like partly calcified cartilage as one would see in the arytenoid cartilages. The preepiglottic space contains both fat and fibrous elastic tissue giving a bright range of intensities. Lymphoid tissue near the base of the tongue is brighter in signal than cartilage but not as bright as fatty tissue (table 1).

Phonation studies and physiologic maneuvers are not possible because of the long scanning times. There is considerable variation in the normal patients in the amount of abduction of the true and false vocal cords that takes place during quiet respiration. When the true vocal cords are completely abducted orientation is possible by noting the convergence of bright signal in the thyroid symphysis with the low signal coming from the thyroepiglottic ligament in the sagittal plane. This juncture denotes the level of the anterior commissure of the true vocal cords.

Sagittal sections of the larynx off-midline became quite confusing with regard to identification of intrinsic laryngeal structures. They can be extremely valuable for demonstrating other vascular and lymph node structures within the neck [1–3].

The sagittal plane was best for evaluating the airway, the epiglottis, and preepiglottic space; the subglottic region about the anterior commissure; and lymphoid tissue about the tongue base. The identification of cephalocaudad extensions of pathologic processes is extremely important for voice conservation surgery or precision radiation therapy of tumors. Considerable use of both the sagittal and coronal planes can be anticipated.

Coronal Plane

As mentioned earlier, the degree of abduction and adduction of the true and false cords shown on coronal scanning is quite variable. The delineation of the true cords, ventricle, and false cords as shown in figure 2 is the exception rather than the rule. In all cases the position of the true and false cords could be identified even when abduction was almost complete. The false cords are consistently bright because of the abundance of loose areolar tissue and glands in the submucosa.

The position of the thyroid alae is frequently unclear, and bright signal from paralaryngeal space obscures the lack of signal of calcified thyroid alae. The bright signal of loose areolar tissue in the paralaryngeal space parallels the mucosal surface of the lateral walls of the larynx and blends anteriorly with hyaline cartilage which is frequently present in the parasymphyseal region. The thyroarytenoid muscle that makes up the major bulk of the true vocal cord shows as a narrow-band low-signal region just above the level of the arch of the cricoid. The cadaver larynx specimen gives a spurious impression of this being a bulky muscle because of the collapsed state of the larynx. In our living patients the low signal of the thyroarytenoid and vocal muscles measured about 1–3 mm in a vertical dimension.

The 4-mm-thick sections at 7 mm intervals proved quite adequate for demonstrating the major bundles of the intrinsic and extrinsic laryngeal musculature. In our limited experience the addition of T2-weighted images did not yield significant additional anatomical information.

Axial Plane

The axial projection is best suited to show the paralaryngeal spaces and anterior margins of the pyriform sinuses (fig. 3). The preepiglottic space is well demonstrated in this projection by high signal from the loose areolar tissue. In the midline there may be low-signal bands due to the fibrous ligaments extending from the lower thyroid symphysis to the petiole of the epiglottis and from the hyoid bone to the upper body of the epiglottis. The exact limits of the posterolateral margins of the thyroid cartilage can at times be difficult to discern

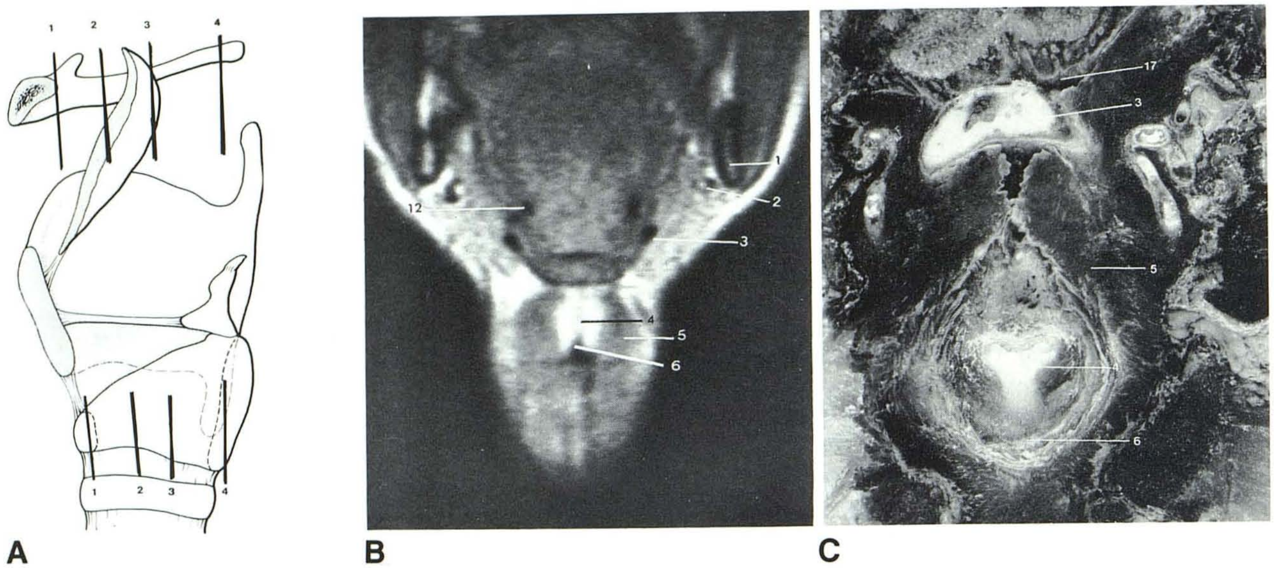


Fig. 2.—Coronal sections of larynx using SE technique, 28 msec TE, 500 msec TR, 3-4-mm-thick sections, and 6 mm intervals from center to center of sections. Second set of coronal scans was obtained with shifting of central axis 3 mm to provide slight overlap of sections and to include intervening spaces. Whole organ sections from cadaver selected for comparison show larynx in relaxed state with epiglottis angled much further posteriorly than would occur in living patient. Intrinsic muscle bundles are much thicker in general due to relaxed state of larynx. **A**, Plane of section for coronal scans and anatomic specimens. Normal posterior angulation of epiglottis causes this structure to be sectioned in oblique plane. **B** and **C**, Level 1: immediately posterior to anterior commissure. **D** and **E**, Level 2: mid true vocal cord. **F** and **G**, Level 3: at level of vocal process of arytenoid. **H** and **I**, Level 4: midarytenoid cartilage section. 1 = mandible; 2 = facial artery and vein; 3 = hyoid bone; 4 = symphysis of thyroid cartilage and anterior preepiglottic space; 5 = strap muscles; 6 = inferior thyroid notch; 7 = cricoid ring; 8 = true vocal cord; 9 = laryngeal ventricle; 10 = false vocal cord; 11 = paralaryngeal space; 12 = lingual artery; 13 = laryngeal vestibule; 14 = carotid vessels; 15 = superior preepiglottic space; 16 = region of thyroid cartilage; 17 = vallecula; 18 = pharyngoepiglottic fold region; 19 = pyriform sinus; 20 = aryepiglottic fold; 21 = arytenoid cartilage; 22 = cricoid cartilage; 23 = lateral cricoarytenoid muscle; 24 = thyroarytenoid muscle; 25 = epiglottis; 26 = vocal process of arytenoid; 27 = tongue base; 28 = thyrocricoid joint. Alae of thyroid cartilage are not discernible on coronal scan in this patient.

because this is the region for early calcification, and the diminished signal intensity may approximate that of adjacent musculature. Because of the space between contiguous slices, vertical extension of a lesion is much easier to discern on sagittal and coronal sections than on axial projections.

Discussion

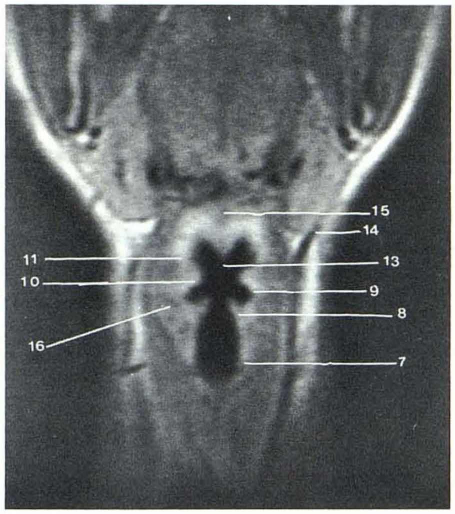
The adjustable surface solenoid coils available for laryngeal imaging provide improved geometry for signal pickup. By comparison with our head coil in the permanent magnet system, a 45%–48% improvement in the S/N ratio was consistently achieved with the surface coil. This high level of signal permitted us to perform some T2-weighted imaging with TEs in the range of 90–110 msec and a 2000 msec TR. An improvement in contrast between areolar tissue and muscle was obtained, but this did not prove helpful in anatomic demonstration because of the small size of the objects to be delineated. There may be a place for these sequences in pathologic states when lymph node disease is being evaluated.

The most important contribution of the surface coil to laryngeal imaging is its ability to combine sagittal, axial, and coronal scans for delineation of deep structures. The demonstration of surface anatomy is good but does not approach that of the clinician's endoscopic images. It is our impression that the demonstration of deep structures approaches that of computed tomography when surface coils are used. Identification of intrinsic musculature is now possible and may prove useful in evaluating functional disorders.

In malignancies of the vocal cords and supraglottic larynx, conservative surgery requires detailed knowledge of the superior and inferior extent of lesions in the paralaryngeal space. Subtle paralaryngeal extension that may be clinically silent is a potential cause of failure of conservative surgery. In addition, the detection of subglottic extension and extralaryngeal extension of tumor is also very important. The anatomic details available with coronal and sagittal scanning would seem ideal in providing this type of information.

REFERENCES

1. Stark DD, Moss AA, Gamsu G, Clark OH, Goodwin FAW, Webb WR. Magnetic resonance imaging of the neck. Part 1. Normal anatomy. *Radiology* **1984**;150:447–454
2. Stark DD, Moss AA, Gamsu G, Clark OH, Gooding GAW, Webb WR. Magnetic resonance imaging of the neck. Part 11: Pathologic findings. *Radiology* **1984**;150:455–461
3. Lufkin R, Larsson S, Hanafee W. NMR anatomy of the larynx and tongue base. *Radiology* **1983**;148:173–175
4. Axel L. Surface coil magnetic resonance imaging. *J Comput Assist Tomogr* **1984**;8:381–384
5. El Yousef SJ, Alfidi RJ, Duchesneau RH, et al. Initial experience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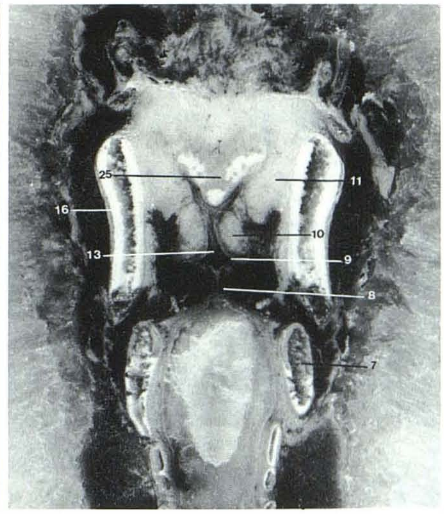
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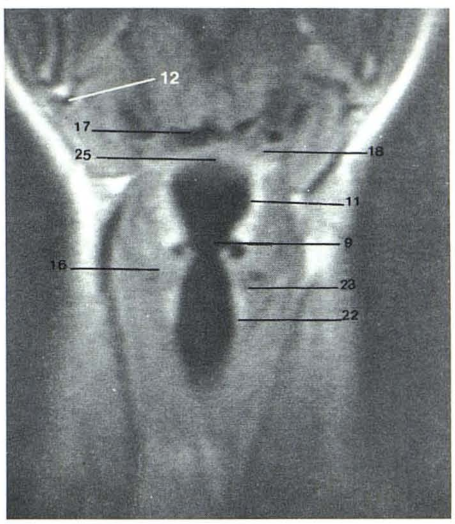
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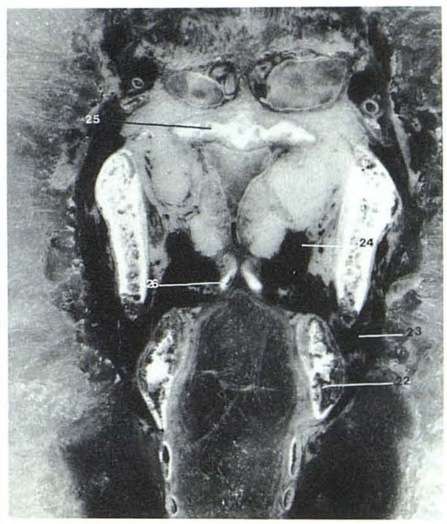
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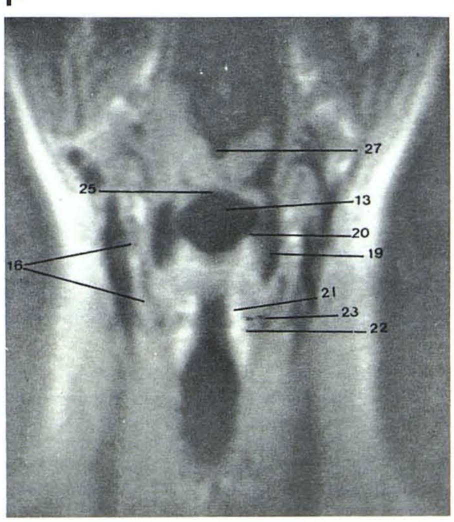
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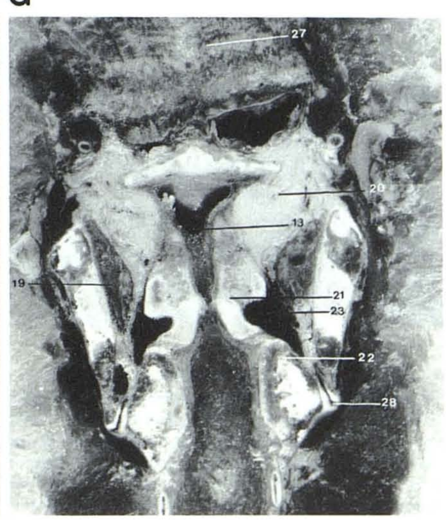
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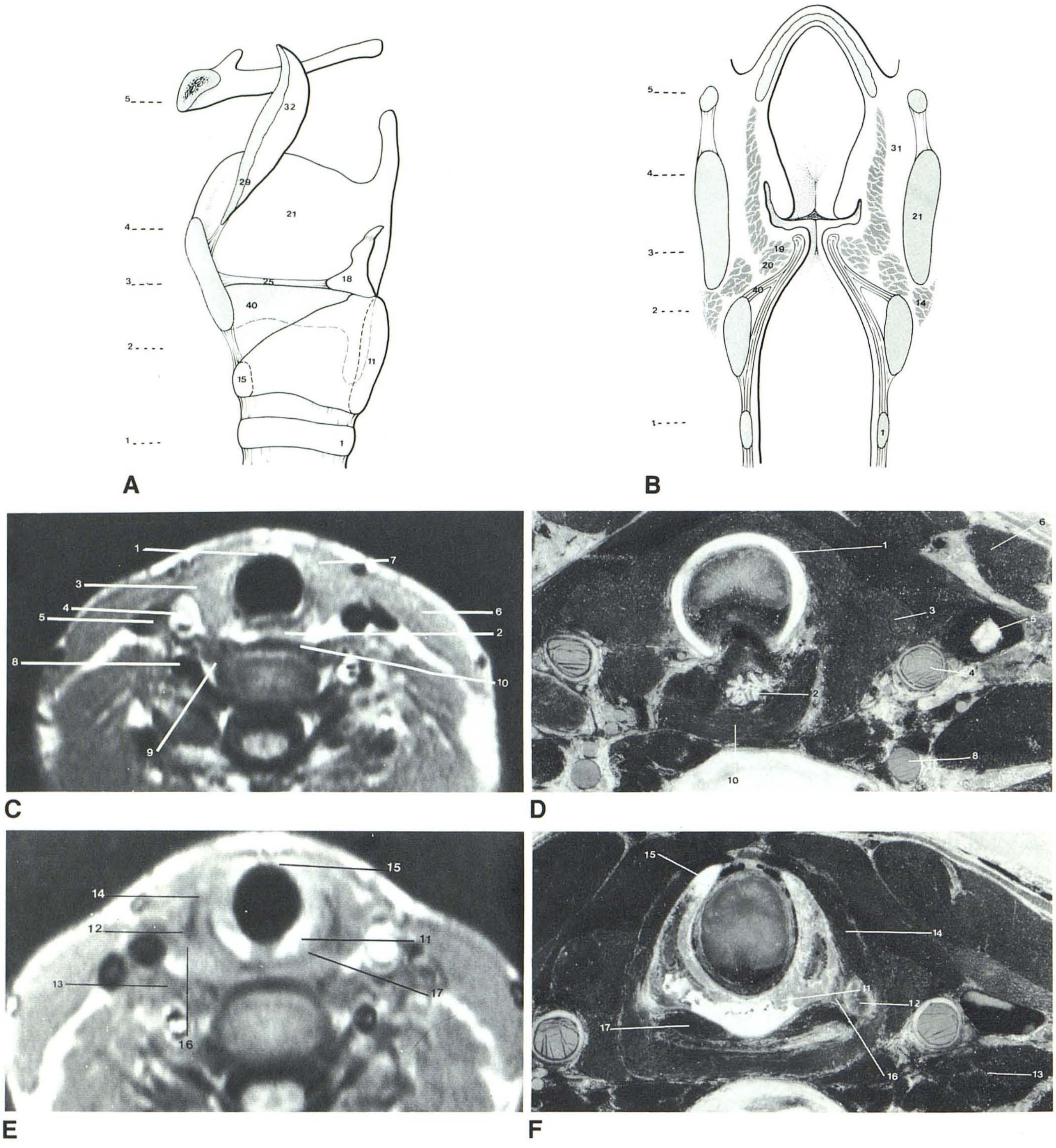
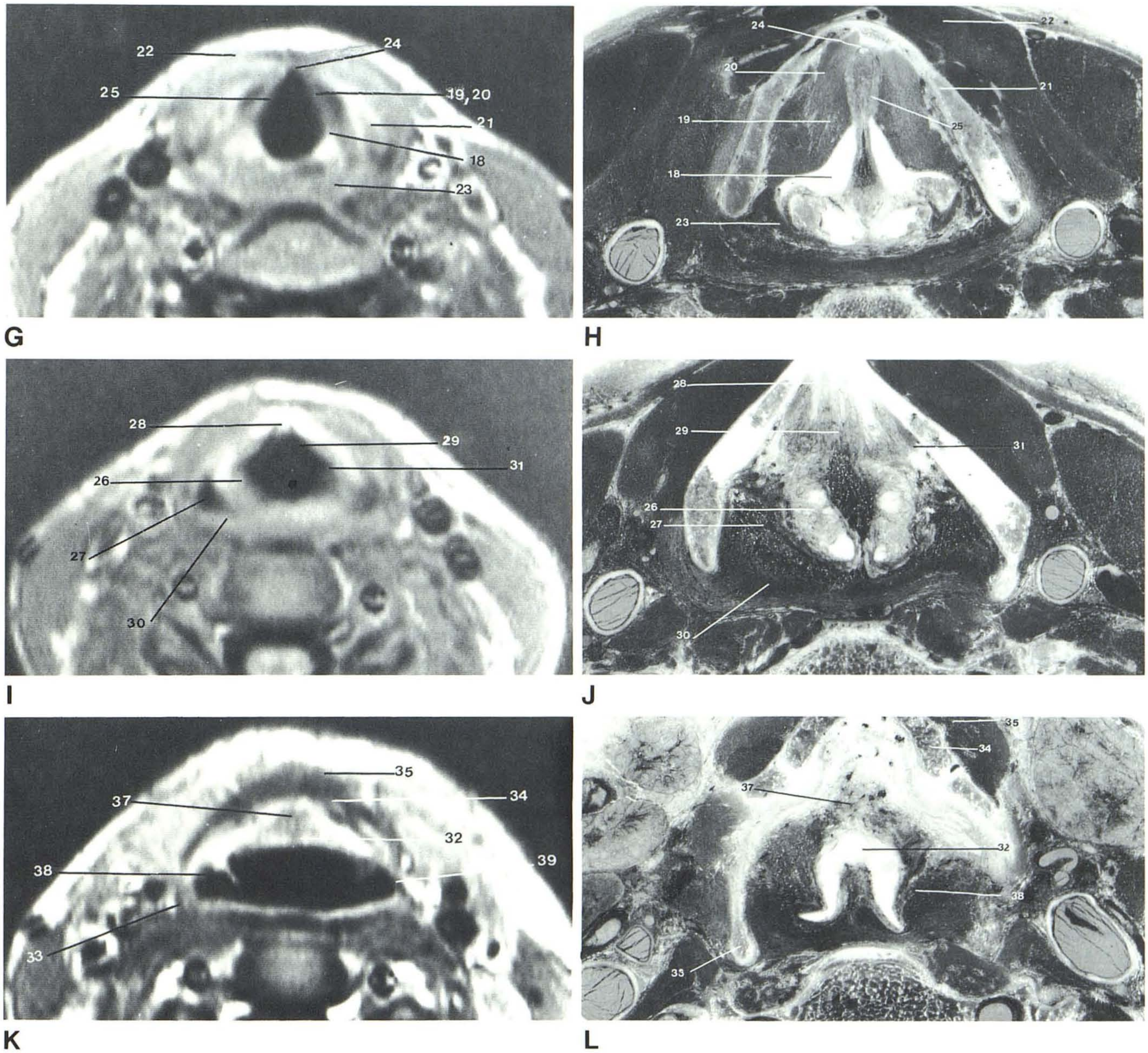


Fig. 3.—Normal larynx. Axial scans. Overlapping sections were obtained to better match 4-mm-thick MR scans with anatomic sections. **A** and **B**, Planes of axial MR sections are shown on left. **C** and **D**, Level 1: tracheal ring. **E** and **F**, Level 2: subglottic. **G** and **H**, Level 3: true cord. **I** and **J**, Level 4: aryepiglottic fold. **K** and **L**, Level 5: hyoid bone. Collapsed state of larynx in postmortem specimens makes exact comparisons difficult. Some blood and secretions in airway of postmortem specimens obscures mucosal detail. Judging by amount of signal coming from cartilage of MR scan there is probably more calcification in anatomic specimen. 1 = tracheal ring; 2 = esophagus; 3 = thyroid gland; 4 = carotid artery; 5 = jugular vein; 6 = sternocleidomastoid muscle; 7 = strap muscles; 8 = vertebral artery; 9 = longus muscle of neck; 10 = cricopharyngeal muscle; 11 = cricoid lamina; 12 = region of inferior cornu of thyroid cartilage;

with nuclear magnetic resonance (NMR) imaging of the human breast. *J Comput Assist Tomogr* **1983**;7:215–218

6. Rauschning W, Bergstrom K, Pech P. Correlative craniospinal anatomy studies by computed tomography and cryomicrotomy. *J Comput Assist Tomogr* **1983**;7:9–13
7. Rauschning W. Popliteal cysts and their relation to the gastrocnemiosemimembranousus bursa. Studies on the surgical and functional anatomy. *Acta Orthop Scand [Suppl]* **1979**;179:1–43
8. Kirchner J. Pathways and pitfalls in partial laryngectomy. *Ann Otol Rhinol Laryngol* **1984**;93:301–305



13 = anterior scalene muscle; 14 = cricothyroid muscle; 15 = anterior ring of cricoid; 16 = cricothyroid joint; 17 = posterior cricoarytenoid musculature; 18 = vocal process of arytenoid; 19 = vocal muscle; 20 = thyroarytenoid muscle; 21 = thyroid cartilage; 22 = thryoid strap muscles; 23 = transverse interarytenoid muscles; 24 = anterior commissure; 25 = vocal ligament; 26 = aryepiglottic folds; 27 = pyriform sinuses; 28 = thyroepiglottic ligament; 29 = petiole of epiglottis; 30 = pharyngeal constrictors; 31 = paralaryngeal space; 32 = body of epiglottis; 33 = superior cornu of thyroid cartilage; 34 = hyoid bone; 35 = thyrohyoid strap muscles; 36 = pharyngoepiglottic folds; 37 = upper preepiglottic space (hyoepiglottic ligaments); 38 = aryepiglottic folds (superior margin); 39 = entrance of pyriform sinus; 40 = conus elasticus.