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The Normal Pediatric Larynx on CT and MR

P. A. Hudgins, J. Siegel, I. Jacobs, and C. R. Abramowsky

PURPOSE: To determine the MR and CT appearance of the normal pediatric larynx. **METHODS:** Fifteen CT scans and 15 MR examinations of children with normal larynges and airways were reviewed retrospectively. Characteristics that were noted included the level of the hyoid bone, calcification and signal intensity within separate laryngeal components, amount of paraglottic fat, anteroposterior airway diameters, and airway contours. Two cadaveric larynges were imaged by CT and MR and were then sectioned at corresponding levels and section thicknesses. **RESULTS:** The larynx is higher in children than in adults, with the hyoid bone found at the C2–3 level in the youngest children (newborn to 2 years). The subglottic airway was narrowest in the youngest children. The hyoid bone was the only laryngeal structure ossified in any of the children. A thin line of high density was seen in the expected location of the thyroid cartilage in some children. The featureless circumferential soft tissue seen around the airway represented the uncalcified laryngeal cartilaginous structures. This was confirmed on gross sectioning of cadaveric larynges. The supraglottic airway contour was triangular or oval, the glottis was shaped like a teardrop, and the subglottic contour was oval. Contours were confirmed on histologic examination of necropsy specimens. **CONCLUSIONS:** This preliminary study suggests that the pediatric larynx differs from the adult larynx with respect to size, position, consistency, and shape, and these differences are reflected on CT and MR studies.

Index terms: Larynx, anatomy; Pediatric neuroradiology

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Anatomists and pediatric endoscopists have long been familiar with the differences between the pediatric and adult larynx. A familiarity with these differences has significant clinical applications. For example, laryngeal lesions are conventionally described as supraglottic, glottic, or infraglottic, and the ability to place the lesion within a region requires a knowledge of the laryngeal anatomy. Unfortunately, the imaging landmarks so familiar in the adult larynx, especially on computed tomographic (CT) scans, appear different in the pediatric larynx. The most striking difference is in the laryngeal cartilaginous structures, which are densely calcified in the adult larynx but in children appear as soft tissue on CT scans. Appreciating the imaging differences can directly affect clinical practice.

We believe that the anatomic and physiologic differences between the pediatric and adult larynx are reflected on both CT scans and magnetic resonance (MR) images. The purpose of this study was to determine the CT and MR imaging appearance of the normal pediatric larynx.

Materials and Methods

Fifteen CT scans and 15 MR studies, obtained in 30 children, were reviewed retrospectively by two neuroradiologists. All children were scanned for indications not referable to the airway, and in none was there any clinical indication of laryngeal or airway disease.

Five CT scans and MR images were available in each of the following age ranges: newborn to 2 years, 2 to 6 years, and 6 to 16 years. All children younger than 7 years were sedated with oral medication, whereas older children were

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From the Departments of Radiology (P.A.H.), Surgery (I.J.), and Pathology (C.R.A.), Emory University School of Medicine, Atlanta, Ga; and Gwinnett Medical Center, Lawrenceville, Ga (J.S.).

Address reprint requests to P. A. Hudgins, MD, Department of Radiology, Emory University School of Medicine, 1364 Clifton Rd NE, Atlanta, GA 30322.

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TABLE 1: Laryngeal structures and details noted on CT and MR studies

Preepiglottic and paraglottic fat
Aeration of valleculae and piriform sinuses
Aryepiglottic folds, true vocal cords
Level of hyoid bone in relation to cervical vertebral bodies
Presence of calcification (CT) and signal intensities (MR) of:
Hyoid bone
Thyroid cartilage
Arytenoid cartilage
Cricoid cartilage
Trachea
Anteroposterior dimension and contour of the glottis, subglottis (3 and 6 mm), and trachea

not sedated. None had nasotracheal or nasogastric intubation. Children were scanned during quiet breathing; breath-hold techniques were not implemented. Scans were obtained either in a neutral position or with slight flexion. CT was performed by using a spiral technique, 3-mm section collimation, 3-mm table feed (pitch of 1), and a reconstruction interval of 3 mm. Nine of 15 CT scans were obtained after a bolus and drip infusion of 2 mL/kg of nonionic iodinated intravenous contrast material. MR images were obtained at 1.5 T with the use of a quadrature head or neck coil. T1-weighted images were acquired with parameters of 500–600/15–30/1–2 (repetition time/echo time/excitations), 3- to 4-mm section thickness, and 190 × 256 matrix. Fast spin-echo T2-weighted images were obtained with parameters of 2000–3000/25–90/1, 4- to 5-mm section thickness, and 256 × 256 matrix.

Presence of gross motion or respiratory artifacts was recorded as none, mild, moderate, or severe (if multiple images were degraded). Anatomic characteristics noted on the CT and MR studies are listed in Table 1. The presence and amount of preepiglottic and paraglottic fat, and the appearance of the vallecula, piriform sinuses, aryepiglottic folds, and true vocal cords were noted. On CT scans, ossification or calcification of laryngeal cartilaginous structures, specifically the hyoid bone, thyroid, cricoid, and arytenoid cartilages, was noted. The level of the hyoid bone with respect to the cervical vertebral bodies was established on the CT examination. MR signal intensities on both T1- and T2-weighted images were observed within the laryngeal cartilaginous and endolaryngeal structures. The contour of the airway at various levels was recorded, and the anteroposterior dimension of the airway was measured on the CT scans at the glottis, 3 mm below the glottis, at the cricoid (6 mm below the glottis), and at midtrachea. Airway contour and careful comparison with the scan above and below each level helped determine where to measure. These measurements were made by consensual agreement between the two readers.

To compare different anatomic levels and to confirm the radiologic appearance of laryngeal structures, two pediatric cadaveric larynges were imaged with both MR and CT. Both children had autopsy-proved normal airways but died of complications of complex congenital heart disease. Neither had had a history of laryngeal or tracheal disease. The first child was born at term and died at 1 month of age. The second child died at 9 months. The larynges were removed en bloc during autopsy, placed in buffered formalin, and imaged within 48 hours. Scans were obtained with a 3-mm section collimation for both CT and T1-weighted MR imaging and with a 4-mm collimation for T2-weighted imaging. CT and MR parameters were the same as those used in vivo, except a higher amperage was chosen and four signal averages were obtained with MR imaging.

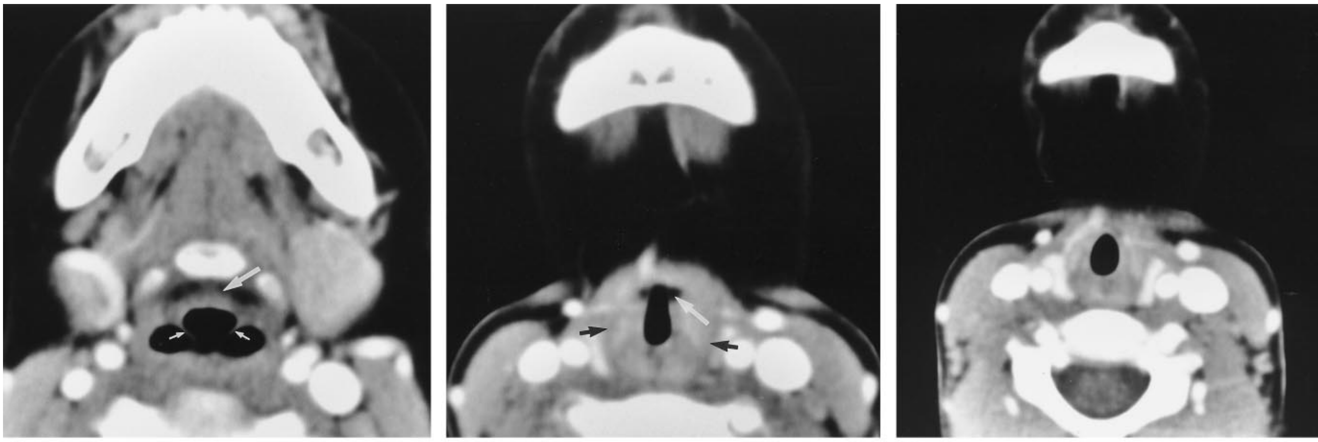
The cadaveric larynges were then sectioned every 3 mm at roughly the same levels as the imaging studies, and the gross and histologic specimens were examined. The airway contour was noted at the supraglottic, glottic, infraglottic, and tracheal levels.

Results

Respiratory motion artifacts were considered to be moderate on three of 15 CT scans. The remaining 12 scans had no significant motion artifacts despite having been obtained during quiet respiration. Eight of the MR images had mild respiratory motion artifacts on at least one sequence, two had moderate artifacts, and one had severe motion artifact, resulting in a suboptimal study. In general, motion artifacts were more significant on MR images than on CT scans, because the entire study, not just individual sections, was affected.

The hyoid bone and suprahyoid epiglottis were located at the C2–3 level in children whose ages ranged from newborn to 2 years, and at the C-3 level in the older children, with the exception of an 11-year-old child, whose hyoid bone was at the C3–4 level. The level of the hyoid varied slightly depending on how much the neck was flexed during the scan. The larynx was generally noted to be located behind the mandible, regardless of neck position during imaging (Fig 1).

On CT scans, the hyoid bone was densely ossified in all children. The synostosis between the hyoid body and the paired lateral greater horns was not fused and appeared as a discrete radiolucency in all children (Fig 1). None of the CT scans showed gross calcification or ossification in the thyroid, arytenoid, or cricoid cartilages. However, the thyroid cartilage appeared as a thin, linear high density in four of five children in the youngest group, in four of five in the 2- to 6-year-old group, and in four of five in the oldest group (Fig 2). High density without frank calcification was present in the cricoid cartilage



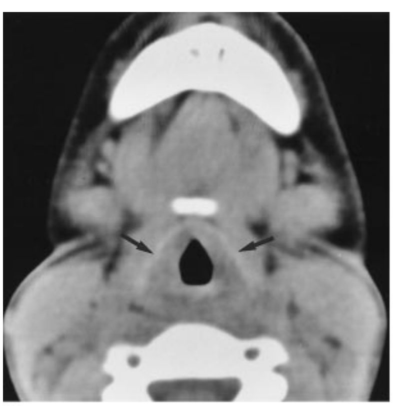
A B C

Fig 1. A 4-year-old girl with no airway disease.

A, Contrast-enhanced CT scan at the level of the hyoid bone, which is densely calcified, shows that the body and lateral greater horns are not fused. The thin aryepiglottic folds (*small arrows*), piriform sinuses, and preepiglottic fat (*large arrow*) are seen clearly. The larynx is on the same level as the mandible.

B, CT scan at supraglottic level, immediately above the true vocal cords, shows the laryngeal ventricle (*white arrow*) anteriorly. There is little paraglottic fat. The cartilaginous structures (*black arrows*) are uncalcified and featureless. The airway contour is oval.

C, CT scan at glottic level. The featureless, circumferential soft tissue around the airway represents the uncalcified thyroid, arytenoid, and cricoid cartilages. The mandible is still seen anteriorly on the same axial plane as the larynx.



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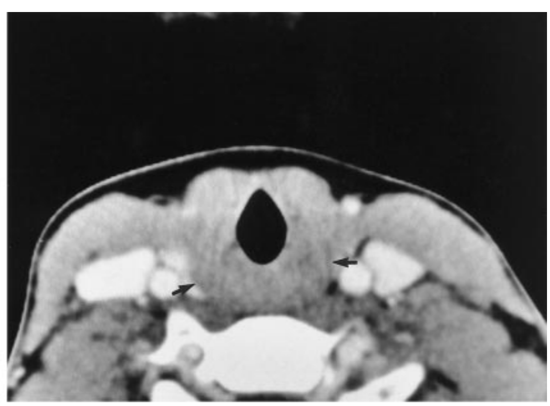

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Fig 2. A 9-month-old boy with no airway disease. Unenhanced CT scan shows linear high density (*arrows*), presumably within the uncalcified thyroid cartilage. The airway contour is teardrop shaped, probably at the true vocal cords. The larynx is seen at the same plane as the mandible.

Fig 3. A 14-year-old boy with no airway disease. CT scan at the glottic level depicts featureless characteristics of the larynx, which appears as circumferential soft tissue (*arrows*) around the airway. This looks distinctly different from the adult larynx.

in one of five in the youngest group, in two of five in the 2- to 6-year-old group, and in one child in the oldest group. The arytenoid cartilage was not of high density or calcified in any of the children. The presence of high density in laryngeal cartilaginous structures did not appear to be age related. The cricoid and arytenoid cartilages were most frequently noted to be of soft-tissue density, and were generally featureless (Fig 3).

The calcified hyoid bone was hyperintense on both T1- and T2-weighted MR images. Other laryngeal cartilaginous structures were isointense with muscle on T1-weighted images and hyperintense with a rim of low signal intensity about the cartilage on T2-weighted images (Fig 4). The individual cartilaginous laryngeal components were more confidently identified on T2- than on T1-weighted images. In general, however, the cartilages and laryngeal soft tissues were less well resolved on MR images than on CT scans, probably because of increased section thickness and respiratory motion artifacts. A general trend was noted for improved visibility of discrete laryngeal cartilaginous structures with age on MR images.

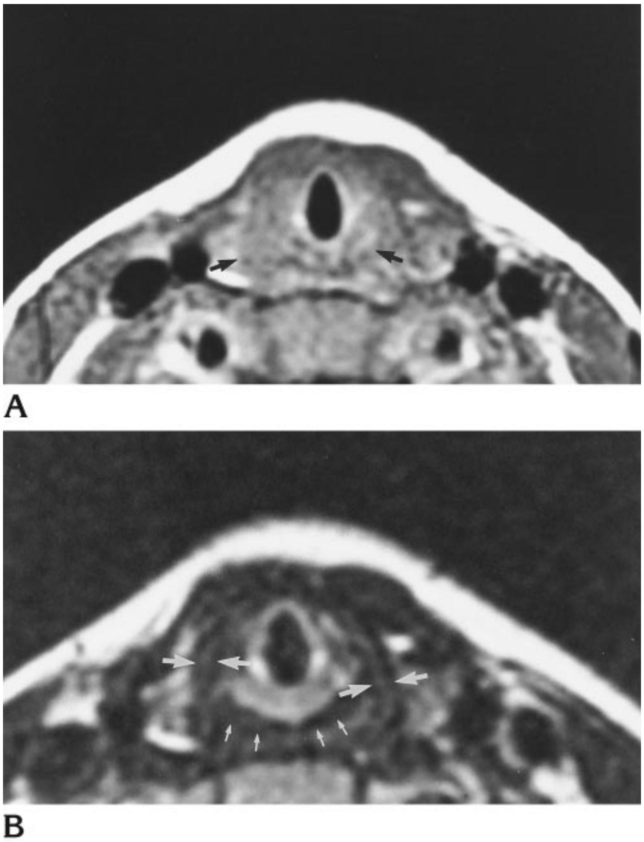

Fig 4. A 3-year-old boy with no airway disease.

A, Axial T1-weighted (400/15/3) MR image, probably immediately beneath the true vocal cords, at the subglottic level. The featureless laryngeal cartilaginous structures (*arrows*) are isointense with muscle.

B, T2-weighted (2600/102 effective/2) MR image at the same level shows the thyroid (*large arrows*) and cricoid cartilages (*small arrows*). The mucosa-covered endolaryngeal soft tissues are hyperintense.

Little preepiglottic or paralaryngeal fat was present on either CT or MR studies in any age group. This was a global, subjective observation made by both neuroradiologists. Both valleculae were aerated in 11 children. In four children (two in the youngest age group and one in each of the older groups), one of the valleculae was unaerated and filled with soft tissue, probably lingual tonsillar tissue. The piriform sinuses and aryepiglottic folds were well seen in all children during quiet respiration.

The anteroposterior airway dimensions as measured from CT scans are given in Table 2. These are reported as a range and not a mean value, since only five measurements were made at each level in each age group. MR airway measurements varied as much as 5 mm in the same child at the same level on T1- and T2-weighted sequences. The anteroposterior dimensions of the airway as measured on MR images were generally 1 to 2 mm narrower than on CT scans, but because of the frequent variation in the same child, a range was not reported. Representative levels at which measurements were obtained are seen in Figure 5.

TABLE 2: Anteroposterior airway dimensions, mm,* on CT

Age, y	Glottis	Subglottic (3-mm) Level	Subglottic (6-mm) Level	Trachea
0–2	7–11	8–9	6–9	6–9
2–6	8–10	7–10	7–10	7–10
6–18	10–13	10–12	10–12	8–12

* Measurements were based on sampling from five subjects in each category and are reported as a range.

The supraglottic airway was generally triangular at the level of the aryepiglottic folds and oval in contour at the false cords. The glottic level was teardrop shaped, the subglottic level was oval, and the trachea was round anteriorly and flat at the posterior membranous portion (Fig 6). These contours and levels were confirmed after sectioning the cadaveric larynges, in which the separate laryngeal cartilaginous structures were readily identified.

Discussion

Although CT and MR examinations are frequently obtained to evaluate the pediatric neck, little is known about the normal CT and MR appearance of the pediatric larynx. This is most likely because plain film radiographic and fluoroscopic studies of the pediatric airway are readily available and easily performed. CT and MR imaging are frequently used in the evaluation of neck masses, but they are not often requested to assess airway disease.

The pediatric larynx differs from the adult larynx with respect to size, both actually and relatively, since, in children, the larynx is smaller in relation to the body (1). The diameters reported in this article were obtained from a small population of patients and do not meet statistical significance. Furthermore, neonates were included in the youngest group along with infants as old as 2 years. Therefore, these measurements should not be used to confirm airway narrowing confidently. Measurements from larger populations of patients, including statistical validation, will be necessary to establish airway diameters that are clinically useful. An

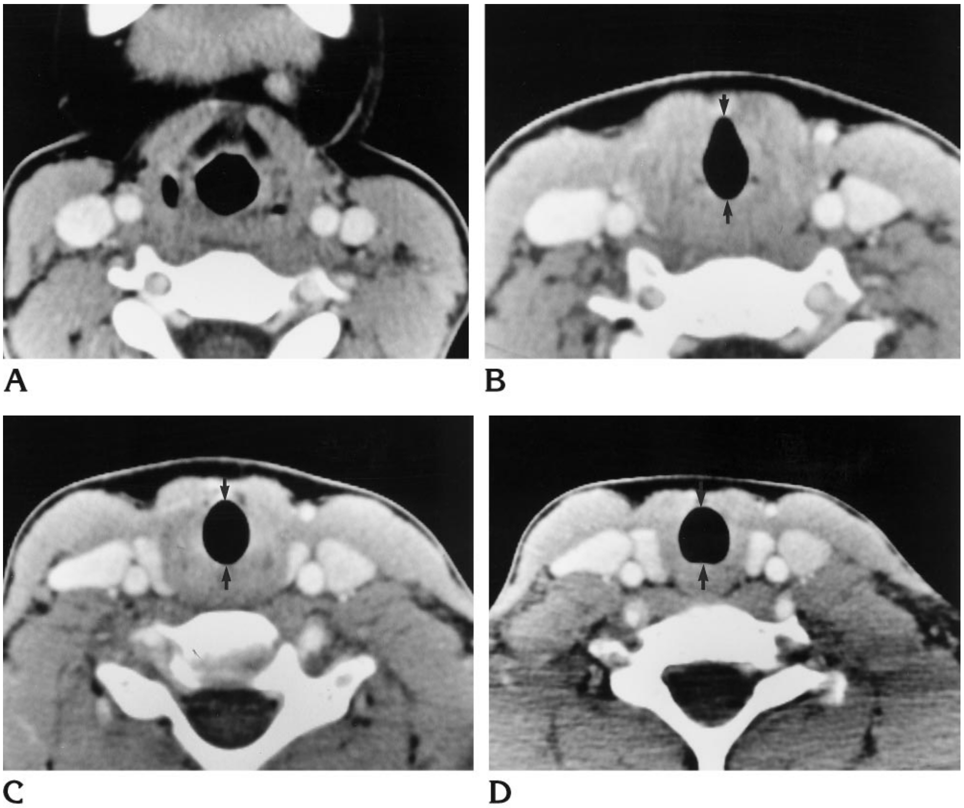

Fig 5. A 14-year-old boy with no airway disease. These levels represent those at which airway measurements were performed in the anteroposterior dimension.

A, Supraglottic level.

B, Glottic level, 6 mm below *A*.

C, Infraglottic level, 6 mm below *B*. The airway contour and anteroposterior diameter on an image 3 mm below *B* appeared similar.

D, Trachea, 9-mm below the glottis. Note the flat posterior membranous portion.

established normal range of airway diameters would be especially helpful in assessing the infant or child with stridor and suspected glottic or subglottic stenosis. Since our goal was not to establish the normal diameter of the lumen in the pediatric larynx, given the small size of our series, we report the range of diameters at various levels for different age groups. The diameter of the subglottic larynx was smaller than the glottic and supraglottic airway in the youngest age group in our series, concurring with the observation made by clinicians and bronchoscopists that this region is the narrowest in the infant and child (1–3). Pediatric endoscopists have stated that a newborn's subglottic airway may be as narrow as 4.5 to 5 mm in the anteroposterior dimension (1–3). However, the smallest infant airway in our series measured 6 mm on CT scans. This variation of 1 to 2 mm is not surprising in that it may simply result from the inclusion of older children (up to 2 years) beyond the newborn period in our youngest age group.

The anteroposterior diameter of the newborn airway, measured on plain radiographs, has been reported to range from 2 to 7 mm at the level of the fifth cervical vertebra, and 1 to 6 mm at the level of the first thoracic body (4). The lowest range in this radiographic series, 2 mm, is smaller than that reported by endoscopists. Although Griscom (5) reported findings of sagittal airway diameters measured from CT scans, those measurements consisted of the mean sagittal (anteroposterior) dimensions from the glottis to the carina. Separate measurements at each laryngeal level were not reported, as in the current series, so that comparisons are not valid. However, our measurements appear to concur with Griscom's results, and are more compatible with endoscopic findings.

The airway is funnel shaped in infants and children, wider at the supraglottic level and narrower in the subglottic level and cervical trachea (3). This explains why the pediatric larynx is at risk for acquired subglottic stenosis, in which a small degree of obstruction may cause significant compromise. The adult larynx, on the other hand, is a symmetric cylindrical shape, similar in dimensions at both the cranial and caudal end, and therefore less prone to obstruction.

The pediatric larynx also differs from the adult larynx with respect to consistency. Except

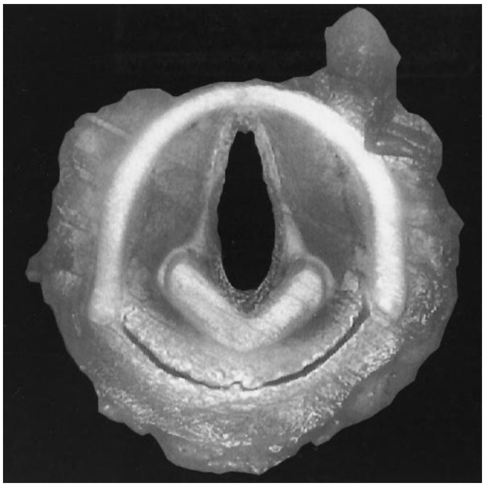

Fig 6. Cadaveric larynx at glottic level, immediately below the true vocal cords, in a 9-month-old boy with no airway disease. The thyroid and cricoid cartilages and undersurface of the true vocal cords are easily recognizable on this gross section. Compare with Figure 1C, in which the cartilage is monotonous and featureless. The collapsed esophagus is seen posteriorly.

for the hyoid bone, the cartilaginous components of the larynx are unossified, and the larynx is soft, pliable, and featureless. The hyoid bone is ossified; that is, it consists of a true bony matrix, osteoid, and osteoblasts. The thyroid, cricoid, and arytenoid laryngeal cartilaginous structures become mineralized or calcified with age, as calcium salts are deposited. Calcified cartilage results when granules of calcium phosphate or carbonate have been deposited in the interstitial substance. The terms *ossified* and *calcified* are often used interchangeably. On plain radiographs, the earliest laryngeal calcification (other than the hyoid) has been reported during the late teens, but is more common beyond the age of 20 (6). This was reflected on CT scans in our study, in which none of the laryngeal components except the hyoid bone were calcified or ossified. This absence of calcification was confirmed on histologic studies of the specimens obtained at necropsy. The linear high density imaged in the thyroid cartilage in the current study is presumably early calcification, which would not be visible on plain radiographs. Premature or congenital laryngeal calcification is rare, and may be associated with stridor (7–10). Acquired tracheobronchial calcification can occur after treatment with warfarin therapy, and may be asymptomatic (11).

Laryngeal cartilaginous structures were isointense on T1-weighted images and were difficult to distinguish from the infrahyoid strap muscles. T2-weighted images best depicted the unossified cartilage as hyperintense with a rim of low signal intensity. This rim was unlikely to represent solely chemical-shift artifacts, as it was prominent on fast spin-echo sequences, and was also seen in the phase-encoding direction. These MR appearances are different than in the adult larynx. Laryngeal cartilaginous structures are generally hyperintense on T1-weighted images in the adult, especially if there is extensive or complete ossification. The cartilaginous laryngeal components are of variable signal on T2-weighted images in the adult.

The observation that there is little paraglottic fat in the pediatric larynx has not, to our knowledge, been made previously. The significance of this is not obvious, but may reflect the small size of the larynx and small volume of paraglottic fat.

Landmarks that are commonly used when interpreting laryngeal CT scans in adults include the calcified arytenoid, thyroid, and cricoid cartilages. As we have shown, in the pediatric larynx, these structures are not calcified, making it difficult to describe the laryngeal level of a lesion. The laryngeal cartilages are so featureless, in fact, that at times it may be difficult to identify a lesion as supraglottic, glottic, or subglottic. Another goal of this study was to describe the airway contour at discrete levels, thus enabling the radiologist to interpret the scans accurately. The supraglottic level is best recognized as somewhat triangular, and the aryepiglottic folds and aerated piriform sinuses are also obvious landmarks. Immediately above the true vocal cords, the airway contour is oval. The true cord level is shaped like a teardrop. This appearance is reliable, even when the vocal process of the arytenoid cartilage, a predictable structure seen on CT scans of the adult larynx, is not calcified. The subglottic region, both at the 3- and 6-mm level, is oval in contour. The trachea is round anteriorly and flat posteriorly at the membranous portion. Careful handling and sectioning of the cadaveric larynges in this study assured that the airway contour was maintained after death. Thus, airway contours were confirmed with the cadaveric larynges, in which discrete but uncalcified laryngeal structures were identified.

The pediatric larynx is positioned higher in the neck than is the adult larynx. In our series, the larynx in the youngest children was at the C2–3 level and was routinely seen posterior to the mandible. In the adult, the hyoid bone is below a line parallel to the top of the third cervical vertebral body (12). This relatively high position of the pediatric larynx probably explains why pediatric laryngeal injuries are uncommon, as the mandible provides protection against traumatic injury (13, 14).

Spiral CT is a technique that allows data to be acquired as a volume set during respiration and while the table is moving. Intuitively, it would seem that motion artifacts, both from table and respiratory movements, would be problematic, but sophisticated interpolation algorithms result in axial images with virtually no motion artifacts. As demonstrated in our series, this development shows great promise for imaging the pediatric larynx and airway. Advantages of spiral CT include the ability to obtain thin section collimation (2 to 3 mm), to reformat high-quality coronal and sagittal planes through the airway, thus displaying the craniocaudal extent of airway lesions, and to obtain high-resolution images during a 15 to 30 second data acquisition period. Lack of respiratory partial-volume artifacts and low radiation dose are additional advantages. Early experience with spiral CT and the pediatric larynx suggests it will complement MR imaging in the examination of this anatomic region.

Conclusion

The supraglottis, glottis, and infraglottis are important clinical and surgical landmarks. Identifying the location of a lesion, such as a focal mass or mucosal tear, poses no difficulty in the adult larynx, as the cartilaginous landmarks are calcified and readily identifiable, enabling the radiologist to locate the endolaryngeal soft tissues accurately. The true vocal cords, therefore, are confidently identified when the dense, calcified vocal process of the arytenoid is seen and the paraglottic fat is no longer seen. The arytenoid is not calcified in the pediatric larynx, and the paraglottic fat is not as prominent, so that other imaging landmarks are important to identify. Furthermore, the uncalcified pediatric cartilaginous structures are almost tumorlike in appearance. Misinterpretation by radiologists unfamiliar with this appearance has led to unnecessary endoscopy.

Our study suggests that the pediatric larynx differs from the adult larynx in four aspects: consistency, size, position, and shape. These differences are reflected on spiral CT scans and MR cross-sectional images. Except for the hyoid bone, the laryngeal cartilaginous structures are not ossified in the pediatric larynx, and appear featureless. The airway is smaller than the adult airway, and is narrowest at the infraglottic portion. The supraglottic airway is triangular and oval, the glottic level has a teardrop shape, and the subglottic level is oval. Finally, the pediatric larynx is positioned higher in the neck, at the C2–3 level, and is seen behind the mandible.

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