Original Article

Ossification of Laryngeal Cartilages on Lateral Cephalometric Radiographs

Muralidhar Mupparapu, DMD[a]; Anitha Vuppalapati, MD[b]

Abstract: This study was undertaken to identify the variations in the physiologic ossification of human laryngeal cartilages by evaluating the lateral cephalometric radiographs of healthy males and females referred to our facility. Lateral cephalometric radiographs of 359 patients (141 male and 218 female; ages 10 to 59 years) referred from various specialty clinics between April 1998 and March 2000 were used. Frequencies and confidence intervals were obtained and tabulated for both thyroid and cricoid ossifications as seen on these cephalometric radiographs. The interobserver agreement was strong for both thyroid (kappa = .986) and cricoid (kappa = .982) observations. Overall, thyroid cartilage was more frequently ossified compared with cricoid. Various degrees of thyroid and cricoid cartilage ossification were found in 186 patients (120 female and 66 male) in the third decade and beyond. Among 173 patients in the first 2 decades (98 females and 75 male), evidence of thyroid ossification was found in 2 male patients aged 14 and 18, and ossification was detected in the cricoid cartilage in 12 patients. There was a preponderance of laryngeal cartilage ossification in men compared with women. Radiographically detectable laryngeal ossification increased with age starting in the third decade. There is a general trend of increase in the ossification of laryngeal cartilages as the age advanced. (*Angle Orthod* 2005;75:196–201.)

Key Words: Thyroid cartilage, Ossification, Laryngeal complex

INTRODUCTION

Ossification and calcification of the laryngeal cartilages have been widely investigated since the original study by Chievitz in 1882.[1] The thyroid, cricoid, and greater part of the arytenoid cartilages consist of hyaline cartilage that undergoes calcification and ossification as part of the aging process. The terms ''calcified'' and ''ossified'' are often used synonymously but calcification always precedes ossification when cartilage becomes transformed into bone.[2] Premature calcification of cartilage in both the larynx and trachea is a rarity.[3]

The thyroid cartilage tends to be visible on the cephalometric and lateral neck radiographs when the ossification starts within the lamina or either of the cornua. The cricoid and arytenoid cartilages also become apparent when the ossification begins within their laminae. Radiographs of the head and neck with soft tissue filters used to study the growth and development of skeletal structures (lateral cephalometric radiographs) as well as the cervical spine radiographic series (c-spine) are very useful in recognizing changes in ossification status of the thyroid cartilage. They also enable us to identify and follow this physiological variation among the patients so that these commonly occurring radiopacities are not confused with foreign bodies.[4,5] Although researchers have used special low kilovoltage peak (kVp) techniques for recording the thyroid and other laryngeal calcifications, lateral cephalometric films may serve as a good diagnostic tool for this purpose. Low kilovoltage radiography of the neck has been used previously to detect malignant calcifications in the thyroid[6,7] and also to detect arthritis in cricoarytenoid and cricothyroid joints.[8]

A good understanding of the anatomy[9,10] (Figure 1) and the knowledge of variations in the laryngeal cartilage ossification is important for all clinicians especially while interpreting head and neck radiographs of patients who exhibit anatomical or functional deviations from normal. Good radiographic interpretation skills are vital for clinicians who use the cephalometric radiographs for craniofacial growth analysis and follow-up in orthodontics, oral and maxillofacial surgery, and other related specialties.

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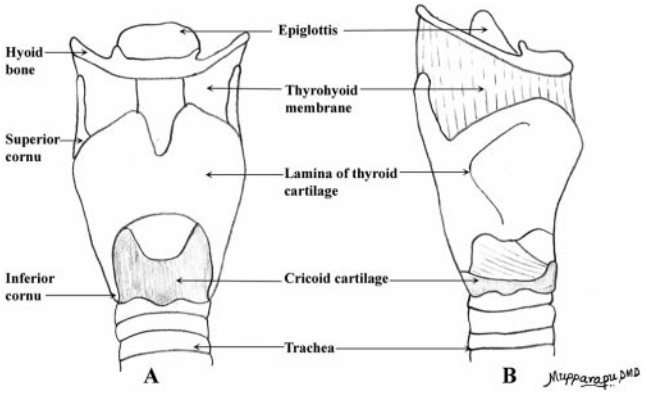

FIGURE 1. Line diagram representing the laryngeal skeleton. The anatomical positions of various cartilages are shown in both the frontal (A) and lateral (B) views. Thyroid cartilage is prominent among them.

MATERIALS AND METHODS

This is a retrospective study conducted using lateral cephalometric radiographs obtained previously at our facility University of Pennsylvania School of Dental Medicine during the period April 1998 to March 2000. An Institutional Review Board Exemption was obtained for the study because the work used the existing data from the radiographic records and did not identify the subjects by name or other identifiable means. Chart number, age, and sex of the patients were recorded anonymously on the film sleeves.

Lateral cephalometric radiographs were obtained on Kodak T-Mat G/RA film (Eastman Kodak Company, Rochester, NY) with a standard 8 × 10 cassette containing a Dupont Cronex Quanta III GB intensifying screen. A Quint Sectographic machine (AMD: American Dental, Hawthorne, Calif) was used to obtain the lateral cephalograms with a source to image distance of 167 cms and object to film distance of 13 cms. An ultralum X-ray grid (Liebel-Flarsheim Company, Cincinnati, Ohio) with a grid ratio of 10:1 was used.

The radiographs were processed in an automatic medical grade film processor, Kodak M20 (Eastman Kodak Company, Rochester, NY) according to manufacturer's recommendations. The cephalometric radiographs where the laryngeal area was not readily observed because of beam shape, orientation of the cassette, or the type of shielding were excluded before the start of the study. The films used in the study were initially evaluated by one of the authors (M. M, an oral and maxillofacial radiologist) in subdued ambient lighting using the transmitted light from a fluorescent viewing box. A medical radiologist, who is experienced in musculoskeletal imaging, later independently evaluated the images. No special training or calibration procedures were initiated other than a consensus on the anatomic locations and general principles of identification of ossification in the head and neck region. The lateral cephalometric radiographs may demonstrate the general area of the superior margin, posterosuperior part of the lamina, and the superior cornu of the thyroid cartilage. The cartilaginous structures are distinguishable radiographically once ossified. The lower border, inferior cornu, and the posteroinferior part of the lamina, if ossified, are also noticed on cephalometric films when the cassette is oriented vertically in the cephalostat, thereby changing the beam shape and size accordingly. Other laryngeal and related cartilages like the cricoid and triticeal cartilages may also be seen within the cephalometric radiograph. The vertical placement of the cassette is occasionally done to accommodate the patients with either a steep mandibular plane or those with an observed increase in the gonial angles.

RESULTS

This study included the radiographs of 359 patients (141 male and 218 female; Table 1) ranging in age from 10 to 59 years. Various degrees of thyroid and cricoid cartilage ossification were found among both males and females beyond the third decade. The frequency of thyroid cartilage ossification among males (n = 141) was 36% and the frequency of cricoid cartilage ossification within the same population was 20%. The frequency of thyroid ossification among female subjects (n = 208) was 19% and the cricoid ossification was 17%.

Data analysis

Interrater reliability was computed as the total agreement between raters. Rates of ossification were computed as relative frequencies for males and females for each cartilage and 95% confidence levels about these estimates were computed by a modified Wald method.[11]

The frequency and 95% confidence intervals are listed in

TABLE 1. Showing the Frequency and 95% Confidence Limits for the Thyroid and Cricoid Ossifications Among the Subjects Studied

Sex	Laryngeal Cartilage Area Ossified	Observation	Confidence Level (%)	95% Confidence Intervals (Modified Wald Method)
Males (n = 141)	Thyroid	51	36.17	28.69, 44.38
	Cricoid	29	20.57	14.67, 28.02
Females (n = 218)	Thyroid	43	19.72	14.96, 25.54
	Cricoid	38	17.43	12.94, 23.05

TABLE 2. Showing the Percentage of Radiographically Observed Thyroid and Cricoid Ossifications in Males and Females by Decade[a]

Sex	Subjects	Decade			
		<Second	Third	Fourth	>Fifth
Males	n[b]	75	27	20	19
	% Ossification (thyroid)	2.7	59.2	75	94.7
	% Ossification (cricoid)	4	18.5	45	66.7
Females	n	98	38	41	41
	% Ossification (thyroid)	0	15.7	36.5	53.7
	% Ossification (cricoid)	9.2	13.1	24.3	34.1

[a] Note: decades 1, 2 and 5, 6 have been merged and denoted as <second decade and >fifth decade.
[b] n indicates number of subjects.

Table 1. The ossification increased as the age advanced. Table 2 shows the percentage ossification among the various decades in both males and females. Very little thyroid or cricoid cartilage ossification was observed within the first 2 decades for both males and females. There was a sudden surge in the prevalence of ossification among the subjects in the third decade and a gradual increase in ossification thereafter. The relationship between age and ossification is consistent with all previous published work.[12–15] The relationship between the rates of thyroid and cricoid ossification in males and females and age was documented. Thyroid cartilage ossification was predominant in both males and females compared with the cricoid cartilage ossification. Males had a greater frequency of ossification for both thyroid and cricoid as compared with females.

FIGURE 2. Cropped lateral cephalometric radiograph of an adolescent male patient showing the ossified superior cornua of the thyroid cartilage (arrow).

DISCUSSION

The framework of the larynx is made up of cartilages that are lined by mucous membrane, connected by membranes and ligaments, and moved by muscles.[9,10] The thyroid cartilage is a major cartilage of the larynx. The skeleton of the larynx (Figure 1) consists of 3 unpaired cartilages (thyroid, epiglottis, and cricoid) and 3 smaller paired cartilages (arytenoid, cuneiform, and corniculate cartilages). In addition, the hyoid bone is closely related functionally to the skeleton of the larynx. The thyroid cartilage consists of two laminae of hyaline cartilage that meet in the midline in the prominent V angle of the Adam apple. The posterior border of each lamina is drawn upward into a superior cornu and downward into an inferior cornu. On the outer surface of each lamina is an oblique line for the attachment of the sternothyroid, the thyrohyoid, and the inferior constrictor muscles. The cricoid cartilage is formed from a complete ring of hyaline cartilage. It is shaped similar to a signet ring and lies below the thyroid cartilage.[9,10]

Ossification within the cricoid cartilage can be identified radiographically even in the presence of the ossification of thyroid lamina. Radiographic identification of the thyroid cartilage is carried out initially by identifying the epiglottis and following the cartilage down to the superior cornu and eventually to the lamina and the inferior cornu. Ossification enhances the cartilaginous outline. Physiologic ossification cannot be differentiated from any form of metastatic calcification if it occurs within the cartilage in the absence of any specific clinical manifestations.

Terminal differentiation and mineralization of human thyroid cartilage occurs usually after the end of adolescence. At that time, most of the previously cartilaginous human skeletal elements have become ossified and the epiphyseal plates are in the process of closing. Ossification normally starts in both sexes at the posterior border, the lower margin, and the inferior horn of the thyroid cartilage.[14] Ossification commences about the 25th year in the thyroid cartilage and somewhat later in the cricoid and arytenoids. By the 65th year, these cartilages may be completely converted into bone.[10] The female thyroid cartilage never ossifies completely, leaving the ventral half cartilaginous.[14] Other permanent cartilages, including first rib cartilage and bronchial cartilage also start to mineralize and ossify after the end of adolescence. Figure 2 shows an unusual early occurrence of thyroid cartilage ossification in a 14-year-old male subject.

The laryngeal skeleton is made up of several components that are composed initially of hyaline cartilage. With aging, the corniculate and cuneiform cartilages, the epiglottis, and the apices of arytenoids are transformed into elastic carti-

lage.[9] The thyroid, cricoid, triticeal, and the greater part of the arytenoid cartilage remain hyaline and may undergo calcification or endochondral ossification (or both) and become visible radiographically. The elastic cartilage never ossifies.[9,10] Although the thyroid cartilage frequently shows ossification after 20 years of age, it is not rare to see ossification below that age.[10] Vlcek[15] showed that estimation of an individual's age can in some cases be done by taking advantage of the degree of progression of thyroid calcification so long as the cartilage has remained preserved. This method has been used in paleoanthropology and forensic medicine to estimate the age of unknown skeletal remains.

Hately et al[16] have an excellent description of the stages of ossification of thyroid cartilage. They mentioned that ossification begins in the inferior portion of the posterior third of the lamina and in the inferior horn. They added to that ossification of the upper portion of the posterior third of the lamina and forward along the inferior margin of the anterior two-thirds of the lamina. For the first time, these authors presented the concept of ''radiolucent windows'' representing the unossified portions of the thyroid cartilage. On occasion, even 2 windows (an anterior and a posterior) were observed in their study, representing the concomitant ossification from 2 different ossification centers. Von Glass and Pesch[12] described 4 ossification patterns of thyroid cartilage ossification, ie, horizontal-caudal, vertical-lateral, vertical-median, and oblique. They proposed that ossification of laryngeal cartilages occurs because of their deformation by the muscles of the larynx.[12] Ossification and nonossification, according to Von Glass and Pesch, are examples of the same principle, the self-regulating adaptation of connective and supportive tissues to mechanical stresses.[12]

The variability of ossification of the laryngeal cartilage makes prediction of a pathologic condition from plain films unreliable. Frequently, the partly ossified cartilages create a diagnostic problem for the radiologist examining for foreign bodies. Within the laryngeal complex, the superior margin of the cricoid lamina often ossifies early, before the remainder of the signet portion of the cricoid. This linear ossification is often mistaken for a foreign body.[3] The triticeous cartilage in the posterior thyrohyoid ligament also mimics a foreign body. Less commonly, the ossified arytenoids and the cornua of the thyroid cartilage may be mistaken for foreign bodies. Diagnosis on the frontal film is severely limited because of superimposition of the cervical spine.[3]

Ossification of thyroid and cricoid cartilages may be observed on lateral cephalometric and panoramic radiographs (Figures 3–6, although these are evaluated more precisely on cervical spine series (C-spine). A number of well-known normal variants of branchigenic structures also appear on the lateral cephalometric radiographs of the head and neck.[17] They include long styloid processes, calcified stylohyoid ligaments, and enlarged superior cornua of the thyroid cartilages. Many of these anomalous structures as well

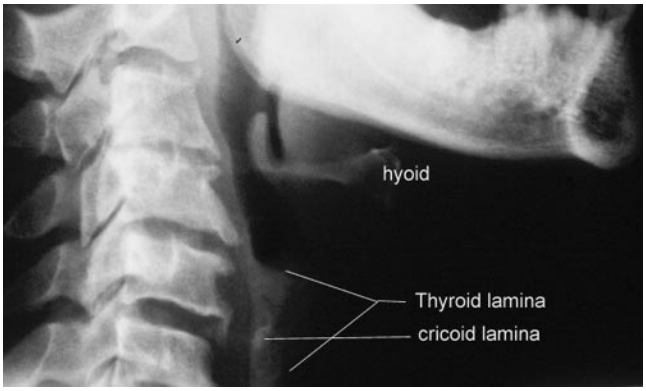

FIGURE 3. Ossified thyroid and cricoid cartilages in a 40-year-old female patient demonstrated on a lateral cephalometric radiograph.

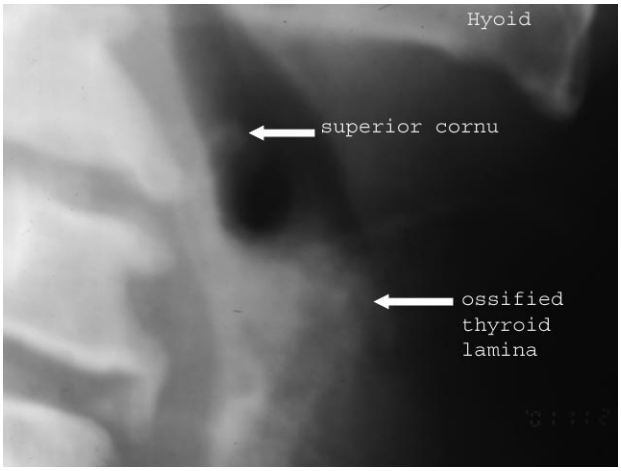

FIGURE 4. Cropped and magnified view of a lateral cephalometric radiograph showing ossified thyroid cartilage in a 59-year-old female patient. The entire thyroid lamina shows diffuse ossification.

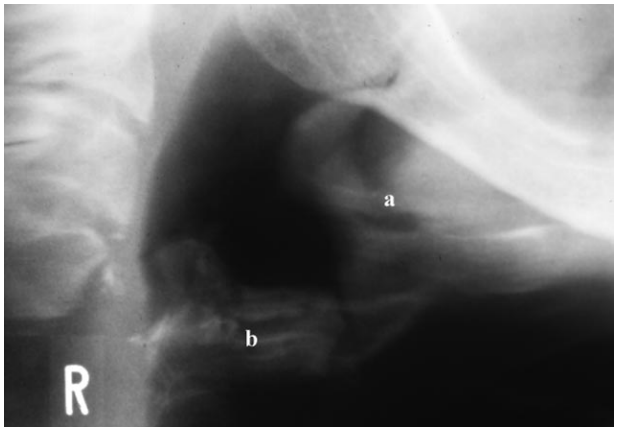

FIGURE 5. Cropped panoramic radiograph of the patient in Figure 4 demonstrating the ossification of the thyroid cartilage on the right side (b) and the double image of hyoid bone (a), seen just below the lower border of the mandible.

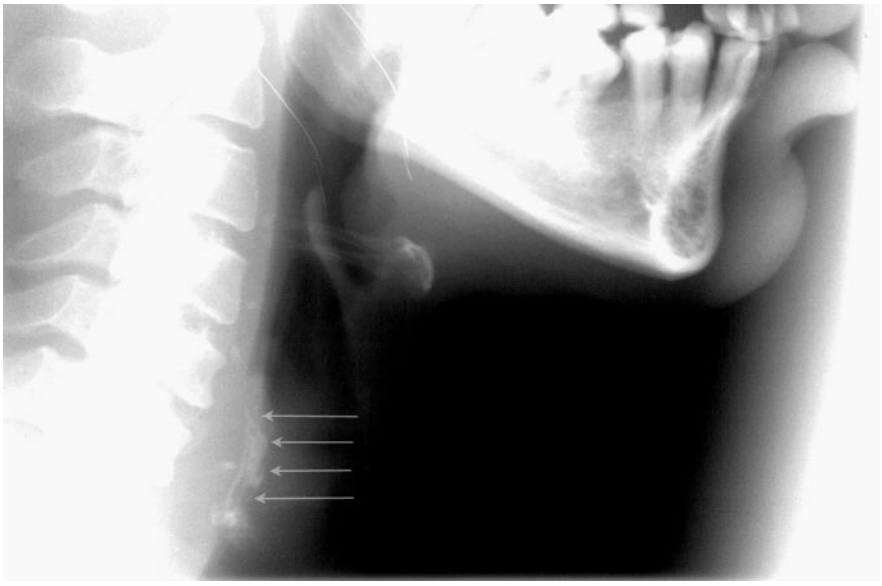

FIGURE 6. Digitally enhanced, cropped lateral cephalometric radiograph of a 32-year-old male patient, demonstrating the ossification of both the thyroid and cricoid laminae extending superio-inferiorly shown by arrows.

as the unusually ossified laryngeal cartilages have been confused from time to time with aspirated foreign bodies.[4] Dystrophic calcification of the lymph nodes and the calcification within the carotid atherosclerotic plaques may be seen on lateral cephalometric radiographs. In addition, panoramic radiographs may reveal the ossified thyroid cartilages as dense opacifications below the image of hyoid bone (Figure 5) bilaterally.

In earlier studies, it was noted that ossification is first seen in the thyroid, followed by cricoid and the arytenoids. In both males and females, the ossification began at the age of 18 to 20 years in the posterior part of the thyroid cartilage.[14,18] Ossification of the laryngeal cartilages is usually symmetrical. Jurik[13] found that the degree and frequency of ossification of the thyroid and cricoid cartilages were lower in the females than in the males, especially in the anterior parts of the cartilages. The author used low voltage radiography (35 kVp to 40 kVp and 120–140 mA), and the patient population had laryngeal tumors not invading the laryngeal skeleton. Jurik[13] also found a dense homogeneous radiographic appearance of the arytenoids present in about 74% of females and 19% of males due to marked calcification of the cartilage. Salman and Kinney[19] reported a similar ossification of a thyroid cartilage on a preprosthetic lateral cephalometric radiograph that did not have any bearing on the routine dental treatment and the ossification was thought to be physiologic.

In the present study, males showed more frequency of both thyroid and cricoid cartilage ossifications than females. The thyroid was more frequently ossified (Table 1). The frequency of ossifications increased with advancing age (Table 2) in both males and females. An interesting phenomenon was the frequency of ossifications observed among males and females for cricoid as compared with thyroid cartilage. Although the upsurge of male cricoid cartilage ossifications is noticeable from the first 2 decades to the third decade (Figure 7), the frequency of male thyroid cartilage ossification was significantly higher in the third decade compared with the first 2 decades (Figure 8). The rate of thyroid ossification was uniform from the third decade and beyond; whereas, the rate of cricoid cartilage ossification was uneven between males and females beyond the third decade. Males showed more increase in the rate of ossification as compared with females. Studies on a larger scale are needed to substantiate this theory. The clinicians should be vigilant while interpreting the lateral cephalometric radiographs for growth and development, espe-

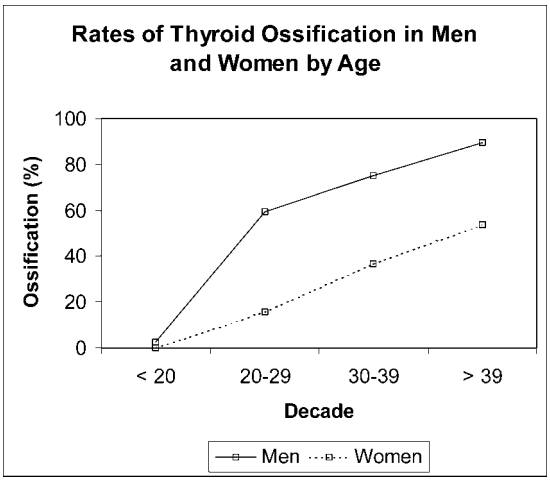

FIGURE 7. Line graph demonstrating the rates of thyroid ossification in men and women by age as seen in the lateral cephalograms of the subject sample.

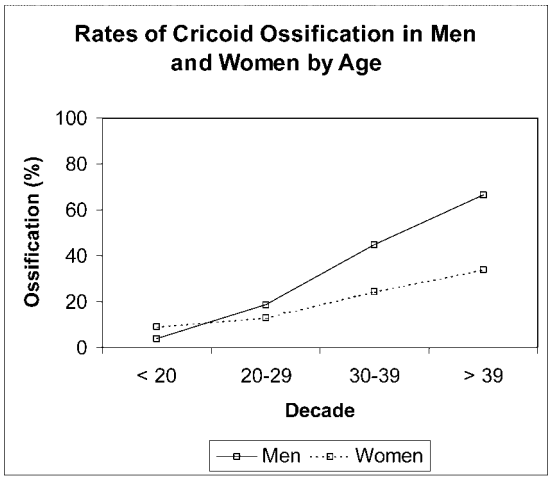

FIGURE 8. Line graph demonstrating the rates of cricoid ossification in men and women by age as seen in the lateral cephalograms of the subject sample.

cially if there is a previous history of trauma to the laryngeal area. Fracture of the superior cornu has been documented on a lateral neck radiograph after a blunt trauma from a blow to the larynx. The radiograph showed fragmentation of the ossified thyroid cartilage with displacement of the superior cornu.[20]

CONCLUSIONS

According to this study, radiographically detectable ossification of thyroid and cricoid cartilages was in general nonexistent before the second decade. Ossification of the thyroid and cricoid cartilages varied from linear shadows to dense laminar calcifications in patients who were in their third decade and beyond. Ossification of thyroid and cricoid cartilages gradually increased with age in both the sexes. If a tendency for thyroid or cricoid ossification is noticed at a very early age, the patient should be examined for signs suggestive of metastatic calcification including calcifications in other structures such as the atlanto-occipital joints, interclinoid ligaments, pineal gland, falx cerebri, etc. If associated ossifications are noticed, referral to a physician may be necessary for a thorough physical examination. The ossification should be considered a physiologic variation in the absence of clinical features indicative of underlying systemic abnormality.[21] The practicing orthodontist need not be unduly alarmed about the ossified thyroid or cricoid cartilages when detected incidentally on lateral cephalometric radiographs. They should be considered along with the other frequently occurring ossifications within the head and neck structures like the triticeal cartilage and the stylohyoid ligaments.

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