Surgical and Radiologic Anatomy (2019) 41:539–542
https://doi.org/10.1007/s00276-018-2174-2

ANATOMIC VARIATIONS

Arch of cricoid cartilage anatomical variation: morphological and radiological aspects

Silvio Antonio Garbelotti Junior[1] · Paulo Ricardo Rocha[1] · Bianca Maria Liquidato[2] · Sérgio Ricardo Marques[1] · Luis Alfonso Arráez-Aybar[3] · Luís Otávio Carvalho de Moraes[1]

Received: 29 June 2018 / Accepted: 18 December 2018 / Published online: 2 January 2019

Abstract
The cricoid cartilage serves as an anatomical reference for several surgical procedures for access to the airway. Additionally, it serves as an attachment point for muscles that move the vocal folds. We present a case where the cricoid cartilage arch is divided into distinct superior and inferior arches, with a fibrous membrane between them. We did not find any similar description to this case in the literature, which makes it unique to date. This type of variation is important knowledge for clinicians and surgeons during airway management in the anterior neck region. The presence of this variation could induce an error during a palpation of the thyroid and cricoid cartilages, realized in clinical examination and surgical or emergency procedures.

Keywords Arch of cricoid cartilage · Anatomical variation · Magnetic resonance image · Morphology

Introduction

The anatomy of the conducting ducts of the human body was first described by Aristotle (c. 350 B.C.). He found that there were two types of conduits, which he believed contained air or other spirits and called them artery (Greek, *aer* = ar; *terein* = to maintain, to lead). The blood vessels, because of their smooth walls, called the *leia* artery (Greek, *leion* = soft, smooth) and believed to be connected to the trachea, probably because the arteries were empty after death. Already the ducts that presented the rough, firm and flexible wall were called *trachea* artery (Greek, *trakheia* = rugoso) (José Carlos Prates, personal communication, May 12, 2018). Galeno in *de Usu Partium* describes the cricoid cartilage according as the second cartilage, presenting a ring shape and it was not given any special name. The term larynx, which means superior part of the respiratory tract, may be associated with its function (Greek, *laimos* = throat, *lerugein* = shout), and the term cricoid [Greek, *krikos* = ring, circle; in the anatomy described by Julio Pollux (second century)], to name the cartilage whose shape resembles a signet ring [1].

One of the most typical features of head and neck development is the pharyngeal arches. These arches appear between the fourth and fifth weeks of development and contribute to the external morphological characteristics of embryos. Specifically, in the case of the human embryos, they form total or partial structures of the face and neck [12].

Each pharyngeal arch is characterized by a bony, cartilaginous and muscular structure, as well as a complex of nerves and vascular components. The mesoderm constituting the arches originates from the paraxial mesoderm, lateral mesoderm, and neural crest cells that migrate to the region. The cartilaginous components of the fourth and sixth pharyngeal arches begin their fusion around the 8th week to form cartilages of the larynx [6, 9, 12].

The genetic basis of pharyngeal arch development is well characterized. The molecular regulation occurs through the expression of the *HOXA*3, *HOXB3, HOXD3* genes, and the *DLX* family [12]. These genes are important for patterning the anterior/posterior and dorsal/ventral axes of the branchial arches [4].

✉ Silvio Antonio Garbelotti Junior
silviogarbelotti@gmail.com

[1] Disciplina de Anatomia Descritiva e Topográfica, Departamento de Morfologia e Genética, Universidade Federal de São Paulo, Escola Paulista de Medicina, Edifício Leitão da Cunha (térreo), Rua Botucatu, 740, Vila Clementino, São Paulo, SP 04023-062, Brazil

[2] Departamento de Morfologia, Faculdade de Ciências Médicas da Santa Casa de São Paulo, São Paulo, Brazil

[3] Departamento de Anatomía y Embriología Humanas, Facultad de Medicina, Universidad Complutense de Madrid, Madrid, Spain

The embryological development of the cricoid cartilage and chondrification centers, as well as its descriptive and topographic anatomy [3] between the fetal and postnatal period, has already been described in the literature [13] (Fig. 1a, b).

Thus, the aim of this case report was to present a rare anatomical fluctuation of the cricoid cartilage from an anatomical view, while considering the embryological aspects, and clinical and surgical implications.

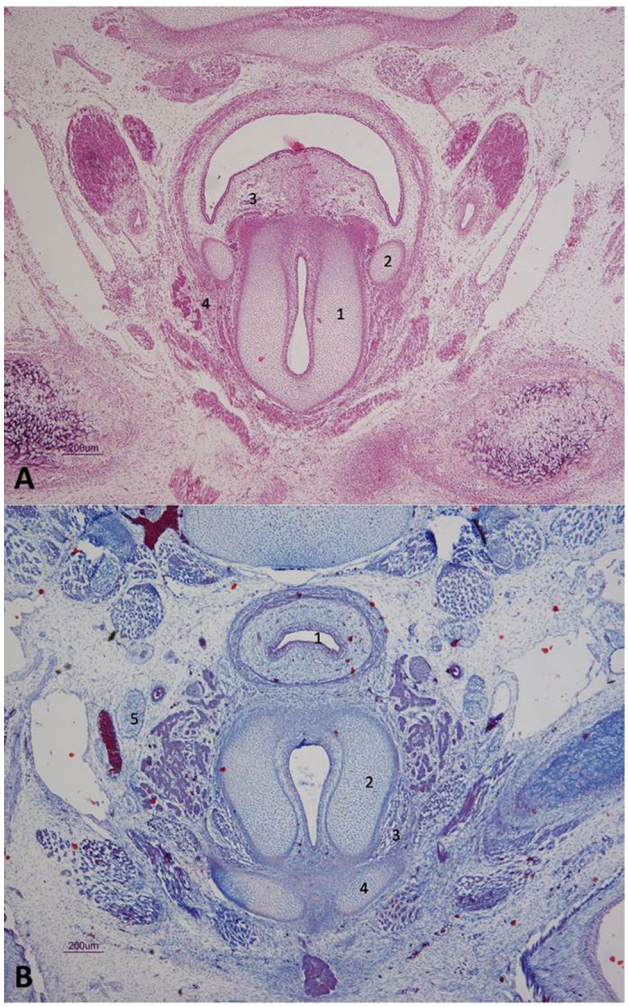

Fig. 1 **a** Stage 20, embryo CAS of the Embryology Institute UCM: the infraglottic cavity in the transverse planes is delimited by the two chondrogenic nuclei for the cricoids. The ventral portion of the common layer of pharyngolaryngeal mesenchyme gives rise to the primordia of the cricothyroid musculature, which are arranged eccentrically in relation to the cricoid arch primordium. (1) Cricoid cartilage, (2) thyroid cartilage, (3) cricoarytenoid muscle, (4) cricothyroid muscle. **b** Stage 22, embryo GI-4 of the Institute of Embryology UCM: the infraglottic cavity, in the transversal sections, is delimited by the cricoid cartilage, in advanced process of condrification, at the level of its lamina and its arch, of which precisely not yet there are signs of condrification for its anterior part. (1) Esophagus, (2) cricoid cartilage, (3) cricothyroid muscle, (4) thyroid cartilage, (5) vagus nerve

Case report

During a routine dissection of a larynx specimen in the Discipline of Descriptive and Topographic Anatomy at the Federal University of São Paulo, we observed a rare variation of the arch of cricoid cartilage. This case report was approved by the Research Ethics Committee of UNIFESP/HU/HSP (0543/2017).

In this case, the arch of cricoid cartilage was divided into superior and inferior arches, with a fibrous membrane between them. Laterally, we observed the arches junction with the lamina of cricoid cartilage without any modification in relation to its normal anatomy (Fig. 2a, b). For a better analysis of this variation, a three-dimensional magnetic resonance image was performed on a Philips device with the following specifications: 120 kV, 400 mAs, 359 mA, 1114 ms, and 100% zoom (Fig. 3).

Discussion

Several laryngeal anomalies are described, and most of them are diagnosed in the neonatal period. In spite of being the most frequent laryngeal anomalies, laryngomalacia and bilateral vocal fold paralysis are considered functional alterations.

Among the laryngeal anatomical variations, the most frequent ones are related to a failure in the recanalization of the laryngotracheal tube. This occurs during embryonic development through the proliferation of cells from the endoderm, which temporarily occlude the lumen of the laryngotracheal tube. The recanalization is supposed to happen around the 10th week of development [12]. Clinical repercussion is variable and mainly related to the opening of the airway [2]. Related anomalies include laryngeal atresia, subglottic stenosis, and laryngeal webs. Posterior laryngeal clefs are rare malformations caused by an incomplete formation of the tracheoesophageal septum, this way communicating larynx and pharynx.

The cricoid cartilage is thicker and stronger than the thyroid cartilage and has a narrow curved arch, with a broad, flatter lamina. It is the only cartilage that forms a complete ring around the airway [11, 13]. The arch duplication could suggest the presence of associated morphological alterations in the infraglottic region, such as a subglottic stenosis. Thus, we propose a surgical intervention for cricotracheal resection followed by a thyrotrophic anastomosis. Thus, we propose a surgical intervention for cricotracheal resection followed by a thyrotrophic anastomosis [5].

The arch of cricoid cartilage is vertical in front and widens posteriorly towards the lamina. The lateral

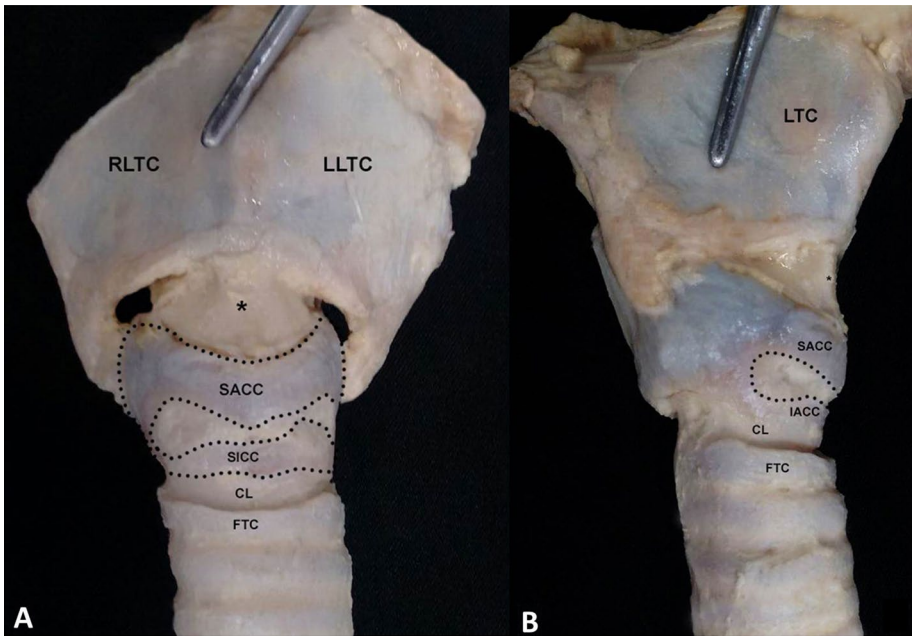

Fig. 2 **a** Anterior macroscopic image of the larynx, showing the laminae of the thyroid cartilage (LTC), the median cricothyroid (asterisk), the cricotracheal (CL) ligaments, and the first tracheal cartilage (FTC). We clearly can see the borders of the superior (SACC) and inferior (IACC) arches of the cricoid cartilage (dotted line). **b** Right lateral view of the larynx. We can observe the union of the superior arch (SACC) and inferior arch (IACC) of cricoid cartilage; and the attachment of the membrane to the arches of the cricoid cartilage (dotted line). *RLTC* right lamina of thyroid cartilage, *LLTC* left lamina of the thyroid cartilage, *CL* cricotracheal ligament. Asterisk: median cricothyroid ligament. *FTC* first tracheal cartilage

Fig. 3 Three-dimensional nuclear magnetic resonance showing the thickness of the superior 8.45 mm (**a**), and inferior arches 5.58 mm (**b**). The image also shows the distance between the arches, 4.64 mm on the right side (**c**) and 6.72 mm on the left side (**d**)

cricoarytenoid muscle is attached anteriorly to the upper border of the arch of cricoid cartilage and is a powerful adductor of the vocal folds [4]. The cricothyroid muscle has a triangular shape and is divided into two parts: oblique and a straight. Both originate anterolaterally in the arch of cricoid cartilage and are attached in the lamina and inferior horn of thyroid cartilage. The cricothyroid muscle slides anteroinferiorly by the thyroid cartilage and over the cricoid cartilage, thereby producing tension, stretching, and adduction of the vocal folds.

Ultimately, the cricoid cartilage has unique anatomical characteristics which serve as a reference for several surgical procedures [10]. Some studies have demonstrated important anatomical points for the accomplishment of endotracheal intubations and later artificial air ventilation [8]. Other authors have demonstrated through the utilization of ultrasound, the upper thoracic anatomy for surgery aids, such as cricothyroidostomy [7].

In all cited procedures, palpation of the thyroid and cricoid cartilages is essential for the location of the underlying structures and, especially, of the tracheal cartilage and their spaces. The division of the cricoid cartilage into two arches, as presented in this case, could induce an error during palpation, thus causing confusion between the inferior arch of cricoid cartilage and the first tracheal cartilage.

The larynx development starts as a linear cleft at the endodermal floor of primitive pharynx during the fourth week. As this cleft grows deeper, it forms the laryngotracheal tube. During the 5th and 6th weeks, the cleft, that turned in to the opening of the laryngotracheal tube, assumes a "T" shape, because of mesenchymal proliferation of surrounding fourth and sixth pharyngeal arches. This mesenchimal proliferation will form all laryngeal cartilages around the cranial part of the laryngotracheal tube, except epiglottis [12]. These special mesenchymal cells originated from neural crest cells that migrated to the pharyngeal arches. This is what happens during normal embryologic development, and maybe, an insufficient migration of neural crest cells to the sixth pharyngeal arch could have caused this variation in the cricoid arch formation.

In conclusion, we did not find any description similar to this case in the medical and anatomical literature, which demonstrates the importance of our finding, especially for clinicians, surgeons and radiologists during the anterior region of the neck procedures.

Acknowledgements The authors would like to express their most sincere gratitude to Professor José Carlos Prates for his invaluable contribution.

Author contributions SAGJ: conception and design study, case analysis and manuscript writing. PRR: data collection. BML: design study and review article. SRM: data collection and interpretation of data. LAA-A: revising it critically for important intellectual content. LOCM: conception and design study, case analysis and manuscript writing.

Compliance with ethical standards

Conflict of interest The authors declare no potential conflict of interest.

References

1. Arráez-Aybar LA, Bueno-López JL, Raio N (2015) Toledo School of Translators and their influence on anatomical terminology. Ann Anat 198:21–33
2. Birkent H, Durmaz A, Karakoc O et al (2012) An unusual case of anterior and posterior laryngeal cleft together: combined cleft of larynx. Eur Arch Otorhinolaryngol 269:345–348
3. Cohen SR, Thompson JW (1990) Ventral cleft of the larynx: a rare congenital laryngeal defect. Ann Otol Rhinol Laryngol 99:281–285
4. Depew MJ, Lufkin T, Rubenstein JL (2002) Specification of the jaw subdivisions by DLX genes. Science 298:381–385
5. Gallagher TQ, Hartnick CJ (2012) Cricotracheal resection and thryotracheal anastomosis. Adv Otorhinolaryngol 73:42–49
6. Graham A (2002) Development of the pharyngeal arches. Am J Med Genet A 119A:251–256
7. Jang YE, Kim EH, Song IK et al (2017) Prediction of the midtracheal level using surface anatomical landmarks in adults: clinical implication of endotracheal tube insertion depth. Medicine (Baltimore) 96:12:e6319
8. Osman A, Sum KM (2016) Role of upper airway ultrasound in airway management. J Intensive Care 4:52
9. Prades JM, Peo'h M, Petcu C et al (2017) The anterior commissure of the human larynx revisited. Surg Radiol Anat 39:871–876
10. Propst EJ, Ida JB, Rutter MJ (2013) Repair of long type IV posterior laryngeal cleft through a cervical approach using cricotracheal separation. Laryngoscope 123:801–804
11. Reidenbach MM (1997) Borders and topographic relations of the cricoid area. Eur Arch Otorhinolaryngol 254:323–325
12. Sadler TW (2016) Langman embriologia médica, 13th edn. Guanabara-Koogan, Rio de Janeiro, pp 230–233
13. Standring S (2016) Gray's anatomy, 41st edn. Elsevier, London, pp 586–597