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SPECIAL SECTION ON SURFACE ANATOMY
ORIGINAL COMMUNICATION

Vertebral Levels of Key Landmarks in the Neck

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Vertebral levels of key landmarks in the neck are well documented in anatomy texts but are they accurate? This study aimed to investigate the vertebral levels of the hard palate, hyoid bone, thyroid cartilage, cricoid cartilage, and bifurcation of the common carotid artery (CCA) using computed tomography (CT). After excluding patients with distorting pathology, 52 CT scans of the neck from supine adults with a standardized head position (mean age 63 ± 17 years, range 30–94 years; 21 female) were available for analysis by dual consensus reporting. Only the vertebral level of the hard palate (C1) was consistent with contemporary descriptions. Other landmarks were located most frequently at the following vertebral levels: the center of the body of the hyoid bone at C4 (54% of cases); the superior limit of the laminae of the thyroid cartilage at C4 in women (60%) and C5 in men (52%) ($P = 0.02$); the inferior border of the cricoid cartilage in the midline anteriorly at C6 in women (37%) and C7 in men (47%) ($P = 0.008$); and the bifurcation of the left and right common carotid arteries at C3 (left 56%, right 62%). The bifurcation of the CCA was a mean of 1.6 ± 1.2 cm above the superior border of the thyroid laminae. Vertebral levels of key bony/cartilaginous structures in the neck differ from standard descriptions but in the absence of a standardized cervical axial plane have limited value and clinical utility. Clin. Anat. 25:851–857, 2012.

Key words: surface anatomy; hyoid bone; cricoid cartilage; thyroid cartilage; common carotid artery bifurcation

INTRODUCTION

Surface landmarks are important for clinical examination, diagnostic and therapeutic intervention, surgery, and understanding anatomy. The positions of deep structures in the neck are often described in relation to bony or cartilaginous landmarks such as the hyoid bone and thyroid and cricoid cartilages, which in turn are referenced to cervical vertebrae. For example, the bifurcation of the common carotid artery is frequently stated to lie at the upper border of the thyroid cartilage at the level of the C3/4 intervertebral disc or C4 vertebra (Standring, 2008; Drake et al., 2010; Ellis and Mahadevan, 2010; Moore et al., 2010; Sinnatamby, 2011). Some texts qualify this level as being ‘‘approximate’’ (Standring, 2008; Drake et al., 2010) and one states that the bifurcation is ‘‘usually’’ at this level but may be higher near C3 (Sinnatamby, 2011). Only *Gray's Anatomy* (Standring, 2008) illustrates the variability of this surface marking. An accurate knowledge of the level of this bifurcation and its variability is important for surgical approaches, despite the availability of prior imaging. Many cervical surface landmarks were originally defined in cadavers (Burns, 1809; Quain, 1844) although some have been reappraised in living subjects using plain and contrast radiography (Bench, 1963; Stepovich, 1965; Gustavsson et al., 1972; Smith and Larsen, 1979; Espalieu et al., 1986). Unlike many major surface landmarks (Hale et al., 2010), those in the neck are

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Fig. 1. Standardized positioning of the head during CT scanning of the neck.

described reasonably consistently in anatomy texts. But are they accurate? The aim of this study was to reassess key surface landmarks in the adult neck using modern cross-sectional imaging.

MATERIALS AND METHODS

Computed tomography (CT) scans of the neck were prospectively obtained between September and December 2010 from spontaneously breathing supine adults using a Lightspeed VCT scanner (GE Healthcare, Milwaukee, WI, USA) with 0.8 mm slice thickness. Head position was routinely standardized in a carbon fiber head holder (GE Healthcare, Milwaukee, WI) (Fig. 1) with the skull aligned in the Frankfurt plane (a plane passing through the inferior margin of the left orbit and the upper margin of the external auditory meatus). Indications for CT scans varied but included investigation and follow-up for cervical lymphadenopathy. Patients with any distorting pathology such as a goiter, obvious lymphadenopathy, major cervical spine fractures, and cervical segmentation anomalies were excluded. After exclusions, scans from 52 adults (mean age 63 ± 17 years, range 30–94 years; 21 female) were available for analysis by dual consensus reporting similar to that described by Murphy et al., 2010; in 32 scans a vascular contrast agent had been used. Multiplanar reconstruction was performed using a Philips 22 inch LCD monitor (Philips New Zealand, Auckland, NZ) with OsiriX imaging software (OsiriX program version 3.0, 2011).

Vertebral levels were classified according to whether the structure was in the horizontal plane of the upper half of a vertebral body, lower half, or intervertebral disc. Anatomical structures were defined as follows.

Bony Structures

The vertebral level of the hard palate and the center of the body of the hyoid bone were identified from midline sagittal images.

Cartilaginous Structures

The superior limit of the laminae of the thyroid cartilage (Fig. 2) and the inferior border of the cricoid cartilage in the midline anteriorly were determined from sagittal and coronal images and their corresponding vertebral levels recorded.

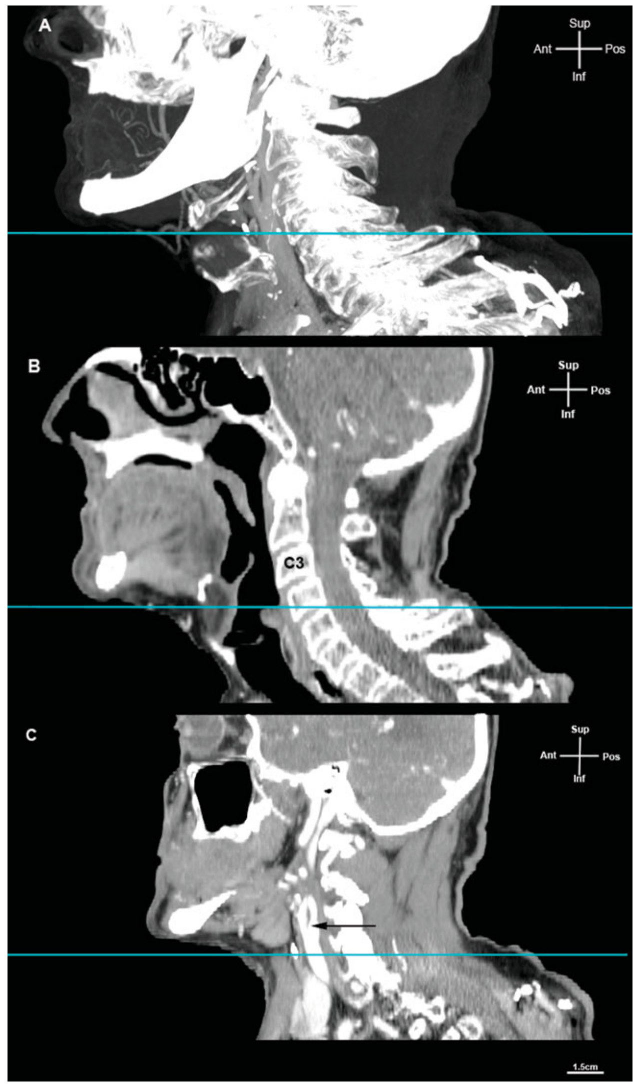

Fig. 2. Sagittal images from a contrast enhanced CT of the neck. **A:** The superior limit of the laminae of the thyroid cartilage. This is a composite image of multiple horizontal slices to show the whole thyroid cartilage (which is partially calcified). In A–C, the superior limit is indicated by a horizontal line. **B:** The vertebral level of the superior limit of the laminae of the thyroid cartilage. **C:** The relationship between the superior limit of the laminae of the thyroid cartilage and the bifurcation of the right common carotid artery (arrow).

The Bifurcation of the Common Carotid Artery

The vertebral level of the bifurcation of the common carotid artery (CCA) determined from its point of division was recorded from sagittal images. It was also noted whether this was in the same horizontal plane as the upper border of the thyroid cartilage and its distance above or below this level was recorded (Fig. 2C).

Intra-rater reliability of all measurements was determined by repeat blind consensus measurements in a randomly selected sample of 15 (29%) scans after an interval of more than 1 month.

Statistical Analyses

Data were analyzed using SPSS statistics version 20.0.0 (SPSS, Chicago, IL). Means and standard deviations for continuous data were compared using Student's *t*-test, and one-way ANOVA. Associations with age and sex were analyzed using full factorial model Pearson correlation. Categorical variables were compared using Chi-squared test and multinomial logistic regression.

Intra-class correlation coefficients (ICC) and the kappa statistic were used for continuous and categorical intra-rater reliability data, respectively (Szklo and Nieto, 2007). Both statistics were graded according to the criteria of Landis and Koch (1977): poor agreement <0; slight 0.00–0.20; fair 0.21–0.40; moderate 0.41–0.60; substantial 0.61–0.80; and almost perfect 0.81–1.00.

Ethical Approval

This study was performed after local ethical committee approval (LRS/09/30/EXP).

RESULTS

Bony Structures

The hard palate was most commonly at the level of C1 (59%), ranging between the base of the skull and the upper half of C2; there was no significant relationship with sex ($P = 0.3$) or age ($P = 0.3$). The center of the body of the hyoid bone was most often at the C4 vertebral level (54%), ranging between the upper half of C3 and the C5/6 intervertebral disc. There was no significant effect of age ($P = 0.7$) or sex ($P = 0.2$). It should be noted that the body of the hyoid bone is up to 12 mm high in men and 11 mm in women (Kindschuh et al., 2010), which is almost equivalent to the height of a typical cervical vertebra (Katz et al., 1975).

Cartilaginous Structures

Overall, the upper limit of the thyroid cartilage was most often at C4 (42%) or C5 (37%) vertebral level but varied between the upper half of C3 and the C5/6 intervertebral disc. There was no significant relationship to age ($P = 0.9$). However, this surface landmark was sexually dimorphic, being significantly lower in men [most often at C5 (52%) in males and C4 (60%) in females; $P = 0.02$].

The inferior border of the cricoid cartilage in the midline anteriorly was most often at C7 (44%), ranging between the lower half of C5 and lower half of T1. It was significantly lower in older subjects ($P = 0.001$). This surface landmark was also sexually dimorphic, being significantly lower in men [most often at C7 (47%) in males and C6 (37%) in females; $P = 0.008$]. Even after adjusting for age and sex differences using multinomial logistic regression, these differences remained significant ($P = 0.01$).

The vertical extent of the cricoid cartilage in the midline posteriorly always overlapped the C6 vertebral level.

The Bifurcation of the Common Carotid Artery

The CCA bifurcation was most commonly at C3 vertebral level (left 56%, right 62%), ranging between lower C2 and lower C5 on the left and C2/3 and lower C5 on the right. The bifurcation of the right and left CCA were at the same vertebral level in 42%, the right lower than the left in 31%, and the left lower than the right in 27%. There were no significant differences in vertebral levels related to age (right $P = 0.2$, left $P = 0.8$) or sex (right $P = 0.3$, left $P = 0.9$).

The CCA bifurcation was above the upper limit of the laminae of the thyroid cartilage in more than 80% of scans (left 85%, right 81%), by at least one intervertebral disc or half of a vertebra. The bifurcation was below this level in 6% of scans bilaterally and at the level in the remainder (left 9%, right 13%). The left CCA bifurcation was at a mean of 1.7 ± 1.2 cm above the upper border of the thyroid cartilage (range 2.2 cm below to 3.6 cm above) and the right CCA bifurcation at a mean of 1.5 ± 1.2 cm above (range 1.8 cm below to 3.3 cm above). There was no significant difference in this distance between right and left sides ($P = 0.1$). There was also no significant difference related to age (right $P = 0.4$, left $P = 0.7$). However, the bifurcation of the CCA was significantly nearer the upper limit of the ipsilateral thyroid lamina in women on the right (1.0 ± 1.3 cm in females compared to 1.8 ± 1 cm in males; $P = 0.02$) but not on the left ($P = 0.2$).

Reliability

Values for intra-observer agreement were all substantial to almost perfect (Table 1).

DISCUSSION

Although there are many inconsistencies in surface landmarks between and within contemporary anatomy texts (Hale et al., 2010), there is general agreement on the vertebral levels of key palpable landmarks in the adult neck. Table 2 contrasts descriptions in selected popular texts with the main findings from our study. Only the vertebral level of the hard palate, mentioned in one text as being level

TABLE 1. Measurement Reliability Statistics[a]

	Kappa	ICC
Vertebral level of the hard palate	0.9	
Vertebral level of the center of the hyoid bone	0.8	
Vertebral level of the upper limit of the thyroid cartilage	0.8	
Vertebral level of the inferior border of the cricoid cartilage	0.7	
Vertebral level of the bifurcation of the right CCA	0.8	
Vertebral level of the bifurcation of the left CCA	0.8	
Distance between right CCA and upper limit of thyroid cartilage		0.9
Distance between left CCA and upper limit of thyroid cartilage		0.9

[a]CCA, common carotid artery; ICC, intra-class correlation coefficient.

with the anterior arch of the atlas (Sinnatamby, 2011), was completely consistent with our data. Vertebral levels of other key landmarks in the neck were different to standard descriptions.

The hyoid bone is consistently described in textbooks as being level with C3 (Table 2) but, from our study, C4 is a more accurate description for the body of the hyoid bone in the median plane. Since the greater horn of the hyoid bone slopes anteroinferiorly to its junction with the body of the bone, the tip of the greater horn may lie at C3 vertebral level; however, this was not examined in our study since texts describing the vertebral level of the hyoid bone either refer to the hyoid bone in general or to both the body and greater horn of the hyoid bone. The position of the hyoid bone is relevant to craniofacial and orthodontic surgeons but anatomic studies from these disciplines have tended to focus on craniometric and craniocervical indices related to the hyoid bone itself rather than its vertebral level (King 1952; Tallgren and Solow, 1987; Sağlam and Uydas, 2006; Deljo et al., 2012). From these studies, tracings of lateral radiographs of the head and neck in erect subjects with the head in a ''natural position'' clearly demonstrate the body of the hyoid bone at the level of C4 rather than C3 (King, 1952; Tallgren and Solow, 1987; Kollias and Krogstad, 1999).

We found no significant effect of age or sex on the vertebral position of the hyoid bone, but the latter was categorized in terms of upper or lower vertebral bodies or intervertebral discs. More detailed analyses using relatively complex measurements in erect adults have found that the hyoid bone is located slightly more inferiorly in older subjects and in men (Tallgren and Solow, 1987; Kollias and Krogstad, 1999). The hyoid bone has also been shown to descend by about 6–7 mm when moving from supine to sitting (Sutthiprapaporn et al., 2008) and to move slightly cranially and caudally with extension and flexion of the cervical spine, respectively (King, 1952).

TABLE 2. Vertebral Levels of Key Palpable Landmarks in the Neck in Contemporary Anatomy Texts and This Study

Landmark	*Gray's Anatomy* (Standring, 2008)	*Last's Anatomy* (Sinnatamby, 2011)	*Clinically Oriented Anatomy* (Moore et al., 2010)	*Gray's Anatomy for Students* (Drake et al., 2010)	*Clinical Anatomy* (Ellis and Mahadevan, 2010)	Most common vertebral level in this study
Hard palate	–	C1	–	–	–	**C1**
Hyoid bone	Approximately C3[a]	C3[a]	C3	–	C3	**C4**
Upper limit of thyroid cartilage	C4 or approximately C3/4	Upper border C4	C4	Approximately C3/4	C4	**C4** women, **C5** men
Inferior border of cricoid cartilage	C6	C6	C6	C6	C6	**C6** women, **C7** men
Bifurcation of common carotid artery	Upper border of thyroid cartilage (approximately C3/4 or C4)	Upper border of thyroid lamina (usually upper border of C4 but may be higher at C3)	Upper border of thyroid cartilage (C4)	Upper margin of the thyroid cartilage (approximately C3/4)	Upper border of thyroid cartilage (C4)	**C3** (mean 1.6 cm above upper border of thyroid lamina)

[a]Both body and greater horn specified at this level.

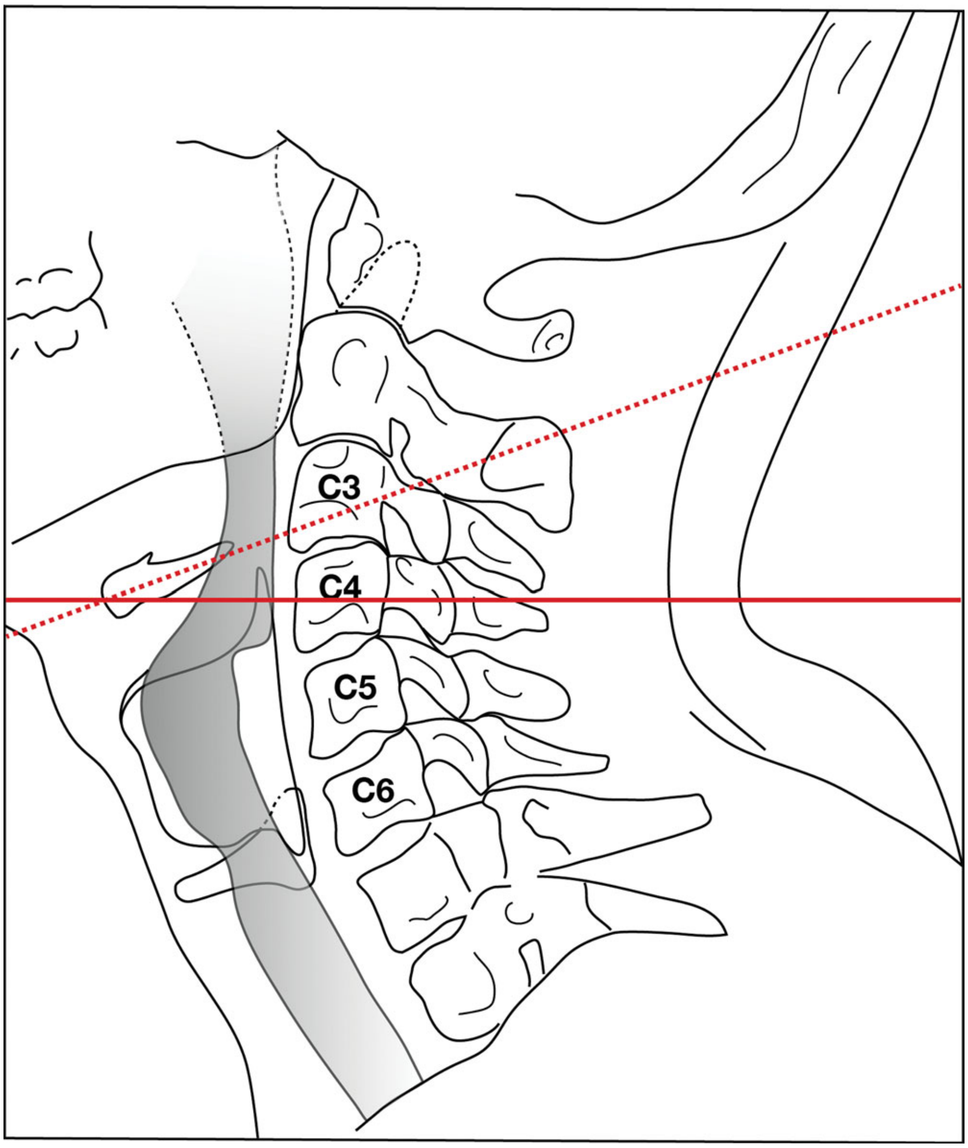

Fig. 3. The vertebral level of structures in the neck depends in part on the curvature of the cervical spine and choice of the reference plane. Unlike the thorax and abdomen, the horizontal plane (red) and axial plane (approximated by the red dashed line) are not the same in the neck. Consequently, the vertebral level of the body of the hyoid bone seen in this tracing from a lateral cervical spine radiograph depends on which plane is used.

Contemporary anatomy texts agree that the upper border of the thyroid cartilage is at C3/4 or C4 (Table 2). However, we found that this vertebral level was sexually dimorphic, being most often at C4 in women and C5 in men. The inferior border of the cricoid cartilage in the midline anteriorly was also significantly different in men and women (C6 and C7, respectively). We selected the lower border of the cricoid cartilage because most major anatomy texts specifically refer to this site when describing the vertebral level of this structure (Lumley, 2008; Standring, 2008; Drake et al., 2010; Ellis and Mahadevan, 2010; Moore et al., 2010; Sinnatamby, 2011), although some of these texts also refer to the cricoid cartilage in general as lying at C6 (Standring, 2008; Moore et al., 2010; Sinnatamby, 2011). Based on our findings, the latter is a better description in that it is more accurate to simply state that the cricoid cartilage lies at approximately C6, since the posterior part of this cartilaginous ring overlapped C6 in all our cases.

The upper border of the thyroid cartilage has been considered a reliable surface marking for the bifurcation of the CCA for more than two centuries (Burns, 1809; Quain, 1844) and remains the standard landmark in contemporary anatomy texts (Table 2), although one text emphasizes the variability of this landmark (Standring, 2008). Our study using cross-sectional imaging in supine adults showed that the CCA bifurcation was above the upper limit of the laminae of the thyroid cartilage in more than 80% of

TABLE 3. The Vertebral Level of the Common Carotid Bifurcation in Adults

	Most frequent vertebral level			
Source	C2	C3	C3/4	C4
Cadavers	(Ribeiro et al., 2006) Brazil ($n = 46$ male cadaver dissections)	(Anu et al., 2007) India ($n = 95$ cadaver dissections)		(Czerwiński, 1981) Poland ($n = 120$ cadaver vascular resin casts) (Civelec et al., 2007) Turkey ($n = 30$ right sided dissections)
Arteriograms			(Smith and Larsen, 1979) Norway ($n = 100$ bilateral arteriograms)	(Espalieu et al., 1986) France ($n = 50$ unilateral arteriograms)

cases, by a mean of 1.6 cm. This corresponded most often to the C3 vertebral level. However, the variability of this level (lower C2 to lower C5) is as important as its modal value. Anomalous bifurcations outside this range, including the thorax (Vitek and Reaves, 1973), are rare.

The method of defining the vertebral level of a structure in the neck is crucially important as the definition of the reference plane significantly affects the vertebral level of all neck structures analyzed in this study. Indeed, this factor may well account for many of the observed discrepancies in vertebral levels between different studies. The curvature of the cervical spine means that the horizontal plane does not necessarily coincide with the axial plane (O'Rahilly, 1997) (Fig. 3). In dissection studies that have recorded the vertebral level of the CCA bifurcation, the plane for determining this level was not defined (Ribeiro et al., 2006; Anu et al., 2007; Civelec et al., 2007) (Table 3). In one such study, cadavers were positioned on shoulder pads with the head extended and rotated; this could significantly distort recorded vertebral levels (Civelec et al., 2007). Ethnic differences may also contribute to observed variations but this has not been studied specifically.

Given the difficulties of defining an appropriate axial reference plane in the neck, the clinical utility of relating cervical structures to vertebral levels is questionable. Further, any such relationships are likely to be distorted during clinical procedures if wedges and pads are used to optimize percutaneous access. Nevertheless, from the perspective of learning topographical anatomy it is helpful to appreciate that the cricoid cartilage lies at approximately C6 and the body of the hyoid bone is most often at the level of C4 in the horizontal plane in the supine individual. The most important clinically relevant conclusion from our study is that the level of the bifurcation of the CCA is very variable but above the upper border of the thyroid cartilage in most individuals. This is supported by a dissection study that found that the bifurcation was a mean of 0.9 ± 0.1 cm above this level (Ribeiro et al., 2006).

Our sample size precluded any investigation of the effects of ethnicity or body habitus. However, patients with distorting comorbidity were excluded. The age range of subjects (30–94 years) would tend to minimize any distortions that might arise from increased CCA tortuosity in individuals more than 80 years of age (Lam et al., 2007). Our results provide further evidence that some surface landmarks currently reported in anatomy texts need to be reconsidered in the light of findings from in vivo cross-sectional imaging. Vertebral levels in the neck have limited clinical utility, but may have some value for understanding topographical relationships.

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