How high do the subclavian arteries ascend into the neck?
A population study using magnetic resonance imaging

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Background. The relationship between the larynx and the subclavian arteries was studied in a series of magnetic resonance images (MRIs) from 50 patients without neck pathology.

Methods. The vertical distances of the excursion of the subclavian arteries into the neck was measured, as was the distance from the cricoid cartilage to the highest point of this excursion. Statistical analysis allows the probability of any given cricoid–subclavian distance occurring in the population to be estimated.

Results. The mean (SD) excursion of the right subclavian artery above the clavicle was 10.4 (11.4) mm. The mean (SD) distance from the cricoid cartilage to the right subclavian artery was 30.6 (14.3) mm, and the data showed a high degree of variance. There was a linear relationship between neck length and cricoid–subclavian distance (r=0.58), which explained some of the variance in the latter, but there was also wide individual variance, which was independent of this regression.

Conclusions. When performing a percutaneous tracheostomy, a ‘safe’ distance between the incision site and subclavian artery cannot be assumed or reliably predicted from the neck length.

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The increasing practice of percutaneous tracheostomy demands a detailed knowledge of the anatomy of the larynx and its adjacent structures. The relationship between the larynx and the great vessels is inconstant, and damage to the latter during percutaneous tracheostomy with a fatal outcome has been reported. Variant arterial anatomy is well recognized in the neck. Usually, the right subclavian artery is one of the two branches of the right brachiocephalic trunk (innominate artery), the other being the right common carotid artery. Its anatomical course is divided into three parts: the first from its origin to the medial border of scalenus anterior; the second, behind this muscle; and the third from the lateral border of scalenus anterior to the outer border of the first rib, where the subclavian artery becomes the axillary artery. In its first part, the subclavian artery ascends about 20 mm above the sternoclavicular joint. But in cadavers, it has been found as high as 40 mm above the joint before arching behind scalenus anterior. It can also arise from below the sternoclavicular joint.

In order to help quantify the risks involved in percutaneous tracheostomy, population data regarding the disposition of these structures and their variance are required. No such data exist. In this study, we set out to determine the magnitude and variance of three morphometric variables by studying the magnetic resonance images (MRIs) of 50 subjects.

Methods
MRIs of 50 patients presenting to the neuroradiology department were reviewed. None of these patients had any pathology related to the lower neck, and had scans with the neck in the neutral position. The T1-weighted coronal series allowed accurate measurements to be made of the position
of the subclavian arteries relative to the cricoid cartilage rostrally, and the clavicle caudally. Such a scan is shown in Figure 1. In addition, MR scans were obtained from four volunteers with the neck in the neutral position and with the neck extended.

Results

Descriptive statistics

Figure 2A–C shows the ‘normal plots’ for the distributions of the following data: (1) the vertical distance of the highest point of the right subclavian artery above the right clavicle (RSA-CL); (2) the vertical distance of the highest point of the left subclavian artery above the left clavicle (LSA-CL); and (3) the vertical distance of the highest point of the right subclavian artery below the cricoid cartilage (CC-RSA). These distributions are considered to be normal. Shapiro-Francia analysis (P-values quoted in Fig. 2 legend) confirms this for RSA-CL and CC-RSA, but indicates some non-normality for LSA-CL. It is reasonable to assume that the data are representative of the population from which those patients undergoing percutaneous tracheostomy come. The mean values (SD) for RSA-CL, LSA-CL and CC-RSA are 11.4 (10.4), 11.3 (9.7) and 30.6 (14.3) mm, respectively.
Probability of any given cricoid–subclavian distance extrapolated to a population

Figure 3 shows a plot of the reciprocal of the probability of encountering a cricoid–subclavian distance less than \( x \), based on a population predicted from our sample data.

Relationship between cricoid–subclavian distance and neck length

Figure 4 shows the regression of these two variables. For this analysis, neck length is represented by the distance between the cricoid cartilage and the clavicle. The relationship appears linear and there is an apparent correlation \((r=0.58)\). The displayed regression equation is highly significant \((P<0.001)\). Using ANOVA, the source of the variance of the data in Figure 4 is analysed. The total variance \((\text{sum of squares}=10002)\) comprises that as a result of the regression \((5840)\) and that as a result of the residuals \((4162)\).

Neutral vs extended neck positions

In the four volunteers who were studied in both neutral and extended neck positions, the mean distance between the cricoid cartilage and the subclavian artery was increased by 11.5 mm \((\text{paired } t\text{-test}, \text{confidence interval (CI) } 2.8–20.2 \text{ mm}, n=4)\) by neck extension. The shape of the neck also appears to change consistently with neck extension. Figure 5 shows how the cross-sectional shape changes from roughly quadrilateral in the neutral position (Fig. 5A), to triangular when extended (Fig. 5B). Extension also causes posterior shift of the sternocleidomastoids, resulting in anterior migration of the carotid sheath.

Discussion

Data distributions

Knowledge of these distributions allows us to predict the frequencies with which we might encounter a given dimension in the population of which this sample is representative. This is an important consideration in the population of patients in whom we perform percutaneous tracheostomies. Figure 3 shows a plot of the reciprocal of the probability of encountering a cricoid–subclavian distance of less than \( x \). For example, the risk of encountering a distance less than 5 mm is 1 in 28, and the risk of encountering a distance of less than 0 mm is 1 in 62.

How much of the variance in cricoid–subclavian distance is due to variation in neck length?

It is reasonable to assume that CC-RSA distance would be greater in those subjects with greater neck length (here quantified as cricoid to clavicle (CC-CL) distance). Figure 4 shows the regression of these two variables. Not surprisingly, there is an apparent correlation and the displayed regression equation is highly significant \((P<0.001)\). However, it is useful to know what proportion of the total variance in the data is due to the regression, and what proportion is due to individual scatter, which is independent of the regression (the residuals). ANOVA reveals that although the regression is highly significant, only 58% of the sum of the squares can be explained by the fact that CC-RSA distance varies with neck length (and is therefore potentially clinically predictable). The remainder (42%) is due to variance in individuals for a given neck length (and is therefore not clinically predictable). This is demonstrated graphically by the prediction intervals plotted in Figure 4. For any value of neck length, we would expect 95% of future subjects to have CC-RSA values between these limits. Longer necks are relatively safer, but cannot be regarded as safe. Note also that even for an outlying neck...
length of 70 mm (2 SD greater than the mean), the probability of encountering a CC-RSA distance less than 25 mm is about 1 in 50, and given that the incision point for percutaneous tracheostomy is usually around 15 mm below the cricoid cartilage, there is little margin for error even here.

**Neutral vs extended neck positions**

One of the limitations to the inferences, which can be drawn from this study, is that the population of ITU patients undergoing percutaneous tracheostomy differs somewhat from the normal patients studied here. The former are invariably intubated, artificially ventilated and may have tissue oedema and other comorbidities. Whether this materially affects the anatomical relationships considered here is unknown.

Another possibly more important difference is that in this study, subjects were imaged with their necks in the neutral position, whereas it is typical to extend the neck when performing a percutaneous tracheostomy, to bring the trachea to a more anterior position, to eliminate skin folds and to make palpation easier. Bertram found that extending the neck in this way actually brought the carotid vessels closer to the tracheal rings.

We examined the effect of neck extension in four normal volunteers. Compared with the neutral position, extension had a modest effect on the cricoid–subclavian distance, which was increased by a mean value of 11.5 mm (CI 2.8–20.2 mm). It is not clear whether this represents a true increase in distance or a ‘parallax’ effect.

**Other anatomical considerations**

A scan from one of the subjects (Fig. 1) shows that the apex of the subclavian excursion into the root of the neck lies some way lateral to the midline. This should mean that if instrumentation is confined strictly to the midline, the incidence of adverse events should be low. The clinical difficulty, however, is that it is not always easy to identify the midline with confidence. Fibreoptic examination helps confirm midline placement of the guidewire, but is of no value in identifying the migration of a dilator through the tracheal wall distal to its insertion site. Of greater importance is the fact that shift of the subclavian artery towards the midline may be a consequence of previous neck surgery. In these circumstances, even if the trachea is easy to palpate and the midline identified with confidence, the vertical and lateral position of the subclavian artery cannot be predicted, and blind percutaneous tracheostomy may represent an unacceptable risk. Ultrasound guidance may help to identify important structures including the subclavian and carotid arteries, and the colour-flow Doppler mode would be particularly useful.

Clearly, there are circumstances in which needle insertion is, by intention, lateral to the midline: namely during internal jugular cannulation. Our results indicate that a proportion of arterial punctures occurring during this procedure might well be subclavian rather than aberrant carotid. The consequences of this occurrence are lesser (in contrast to subclavian puncture occurring during tracheostomy), since no attempts are made serially to dilate the vessel. In summary, there is a wide degree of variance in the height of the excursion of the subclavian artery into the root of the neck. The distance between the cricoid cartilage and this point of the subclavian artery (CC-RSA) is also variable. There is a relatively high probability that the two structures may be at the same horizontal level. Although this distance increases as neck length increases, there is considerable variance even when this trend is accounted for, such that neck-length cannot be reliably used to predict a ‘safe’
CC-RSA distance. This becomes clinically important when confinement of instrumentation to the midline cannot be guaranteed or when lateral vascular structures may have been shifted medially as a consequence of previous surgery. Percutaneous tracheostomy is relatively contraindicated in these patients. Portable ultrasound scanning may be of value in evaluating these patients and also for routine use.

References