BJA

British Journal of Anaesthesia, 121 (5): 1166–1172 (2018)

doi: 10.1016/j.bja.2018.07.013
Advance Access Publication Date: 22 August 2018
Respiration and Airway

# Prevalence of major vessels anterior to the trachea at sites of potential front-of-neck emergency airway access in adults

W. M. Weightman[1,2,*] and N. M. Gibbs[1,2]

[1]Department of Anaesthesia, Sir Charles Gairdner Hospital, Nedlands, Perth, Western Australia, Australia and [2]University of Western Australia, Crawley, Perth, Western Australia, Australia

*Corresponding author. E-mail: william.weightman@uwa.edu.au

## Abstract

**Background**: Several case reports have described anatomical variations that can cause difficulty with front-of-neck airway access, such as major vessels anterior to the trachea. The prevalence of these anomalies is unknown.

**Methods**: We screened 500 consecutive thoracic computed tomography (CT) scans in adult patients performed independently in any public hospital in Western Australia. The prevalence of major vessels anterior to the trachea in the anterior triangle of the neck was determined.

**Results**: In the suprasternal notch, 264 CT scans (53%) demonstrated part of a major vessel anterior to the trachea, most commonly the brachiocephalic artery. At 10, 20, and 30 mm above the suprasternal notch, respectively, 126 (25%), 48 (9%), and 5 (1%) CT scans showed a major vessel anterior to the trachea. None showed a major vessel anterior to the cricothyroid membrane. In the suprasternal notch, a major vessel was anterior to the trachea in 10 of 120 CT scans (8%) that had a manubrio-cricoid distance <25 mm, and 108 of 116 CT scans (93%) that had a manubrio-cricoid distance >50 mm. In a logistic-regression model, increased length of trachea above the manubrium was a strong predictor of major vessels anterior to the trachea in the suprasternal notch, whilst sex, age, thoracic kyphosis, tracheal diameter, and the origin of the brachiocephalic artery were not strong predictors.

**Conclusions**: It is common for patients to have some portion of a major vessel anterior to the trachea at sites where an emergency tracheostomy might be performed.

**Keywords:** brachiocephalic trunk; brachiocephalic veins; emergency treatment; suprasternal notch; tracheostomy

**Editorial decision**: 19 July 2018; **Accepted:** 19 July 2018

### Editor's key points

- The presence of major vessels anterior to the crico-thyroid segment or the trachea can cause difficulty with front-of-neck airway access, but its incidence is not known.
- The incidence of major vessels anterior to the trachea is high (53%), but is much less at the cricothyroid segment.

Medical practitioners may be required to perform a tracheostomy, cricothyroidotomy, or cricothyroid puncture in patients with severe airway compromise.[1,2] In ideal circumstances, these procedures are performed by an experienced surgeon or intensive care physician, possessing day-to-day familiarity of the relevant anatomy, but in emergency circumstances, they may need to be performed by clinicians who do not have extensive surgical training, such as anaesthetists, or emergency department physicians.

Standard textbooks describe the major branches of the aorta originating anterior to the trachea, but coming to lie on either side of the trachea before it enters the anterior triangle of the neck.[3] The left innominate vein crosses the trachea behind the manubrium, so the major veins lie on each side of the trachea in the anterior triangle (Fig. 1A). Variations to this pattern are usually reported as rare anomalies, for example, the occurrence of major vessels anterior to the trachea in the anterior triangle. This anomaly may cause severe morbidity[4,5] or near-miss incidents[6–14] if front-of-neck access is attempted. The variability of the aortic arch and branches,[15–18] and the relationship of these to the vertebral bodies,[19] have been systematically described. However, with the exception of a recent study in the setting of complex cervical surgery,[20] it is not known how frequently medical practitioners may expect to find major vessels anterior to the cervical trachea in a typical patient population. It is also unclear if these anomalies can be predicted from the patient's characteristics, such as gender, advanced age, or marked kyphosis.

The aim of the current study was to estimate the prevalence of adult patients with major vessels anterior to the trachea at sites where emergency front-of-neck airway access may be attempted.

## Methods

Ethics approval was given by the Sir Charles Gairdner Hospital Human Research Ethics Committee, approval 2013-083.

Consecutive computed tomography (CT) scans of the thoracic region in patients more than 16 yr of age at any Western Australia State Health Department Hospital were studied. This included in-patient and outpatient scans from four tertiary hospitals and five secondary hospitals, including weekend and out-of-hours scans. Scans were performed in the supine position, with a small pillow under the head and the

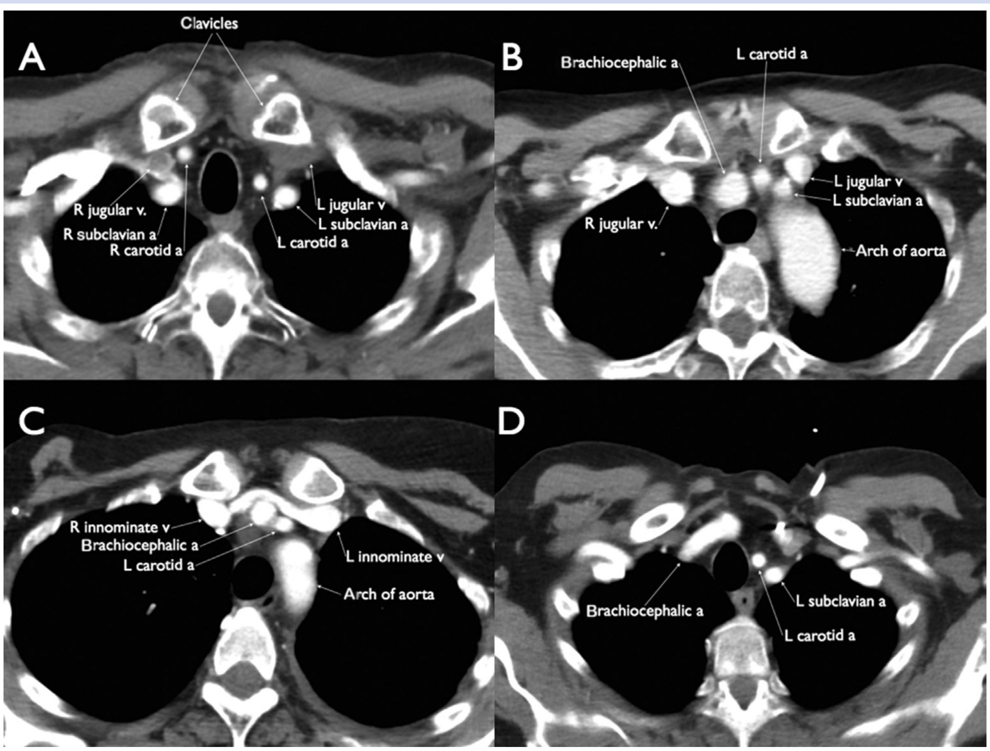


Fig 1. Computed tomography scans of the thoracic region. (A) Normal anatomy, with no major vessels anterior to the trachea in the suprasternal notch; (B) Patient with brachiocephalic artery and part of the left carotid artery anterior to the trachea in the suprasternal notch; (C) Patient with both left innominate vein and brachiocephalic artery anterior to the trachea in the suprasternal notch; and (D) Patient with brachiocephalic artery crossing the trachea 25 mm above the suprasternal notch. a, artery; L, left; R, right; v, vein.

gantry perpendicular to the table. Patient CT scans were included regardless of the diagnostic reason for the scan, with the exception of scans performed for the estimation of coronary calcium score and for the emergency diagnosis of pulmonary embolus: these were excluded because they were performed under protocols that did not include all relevant areas with sufficient resolution. Other exclusion criteria included scans performed with slice intervals greater than 3 mm, if the resolution of the scan did not permit the identification of the arterial structures within the chest, if the suprasternal notch was not included in the scan, if the slice level was not calibrated for distance, or if the scan was performed in the prone position. Otherwise, all consecutive scans over the study period were included.

Repeatability was assessed in a random sample of scans with the same observer making repeat measurements after an interval of at least 1 month. Test–retest performance was estimated by the same observer in a random sample of patients who had undergone a second CT scan of the chest on a different day. Random samples were generated by a table of random numbers.

### Measurements

The location of the suprasternal notch was defined as the first scan slice going in an inferior-to-superior direction with no manubrium visible. The lateral bounds of the suprasternal notch were considered to be the medial borders of the clavicles. The top of the clavicular heads was defined as the most superior slice where the distance between the clavicles was 5 mm more than the intra-clavicular distance in the suprasternal notch. The trachea was defined from the inferior border of the thyroid cartilage to the carina. Vertical distances were estimated using the reconstruction measurement tool. Horizontal distances were estimated using the calibrated slice level. Linear distances between objects in different slices, for example, the distance between the origin and end of the trachea, were estimated by triangulation.

### Specific measurements

An anteroposterior line was drawn from the lateral borders of the tracheal lumen, and measurement was made of the amount of overlap by any major artery or major vein: (i) at the suprasternal notch; and (ii) 10, 20, and 30 mm above the suprasternal notch.

Other measurements included the following: (i) the distance between the suprasternal notch and the thyroid cartilage; (ii) the origin of the brachiocephalic artery, defined as the most inferior slice where the brachiocephalic artery was distinct from the aorta; (iii) the location where the brachiocephalic artery completed crossing the trachea, defined as the most inferior slice where no part of the brachiocephalic artery overlapped the anterior–posterior (AP) projection of the trachea; (iv) the superior extent of the aorta, defined as the most superior slice with any aorta visible; (v) the amount of rotation of the patient's chest as estimated by drawing a line from the centre of the spinal cord to the midpoint of the sternum, and measurements of the brachiocephalic artery origin were taken parallel to this line; (vi) the transverse diameter of the trachea at the suprasternal notch; (vii) the location of the thyroid gland in relation to the suprasternal notch, and this was defined as wholly retrosternal if all the thyroid gland was inferior to the suprasternal notch, partly retrosternal if any part of the thyroid gland was behind the manubrium, or suprasternal if all the gland was above the retrosternal notch; and (viii) the amount of thoracic kyphosis was measured by measuring the angle between the C7/T1 intervertebral disc and the T11/T12 intervertebral disc.

### Statistical analysis

Continuous variables are reported as mean with standard deviation (SD) in brackets. Categorical variables are reported as number and proportion.

### Statistical power

The primary hypothesis of this project was to determine the proportion of patients with a major vessel anterior to the trachea in the suprasternal notch. We aimed to estimate this proportion with plus or minus 5% accuracy. We calculated that 500 patient scans would be required to estimate this if the observed proportion of patients with a major vessel anterior to the trachea was 50%, given an alpha error of 5% and a beta error of 20%. The 50% proportion was chosen as the worst-case scenario in terms of accuracy; any other proportion would require fewer patients. For example, if the observed proportion was 5%, then 500 patients would estimate the true proportion with plus or minus, 2% accuracy.

Repeatability and test–retest agreement were estimated by Pearson correlation coefficient.

Using a logistic-regression model, we examined the association between the presence of a major vessel over-riding the trachea in the suprasternal notch and clinical features, including sex, older age, a short trachea, a wide trachea, a common origin of the brachiocephalic and carotid arteries ('bovine aorta'), a high origin of the brachiocephalic artery relative to the carina, a more leftward origin of the brachiocephalic artery relative to the trachea, and a low-riding manubrium. We assessed the position of the manubrium in relation to the trachea in the longitudinal plane by measuring the proportion of the total tracheal length above the suprasternal notch. In the logistic-regression model, the dependent variable was any overlap of a major vessel with the AP projection of the trachea at the suprasternal notch; the independent variables were the predictive variables described previously, with continuous variables categorised into terciles.

Because the tracheal length can be estimated only by imaging, we also tested if this variable could be substituted by the length of trachea above the suprasternal notch, as this could feasibly be estimated at the bedside.

## Results

There were 500 consecutive patient CT scans that met the inclusion criteria. This required recruiting a total of 543 initially, as 43 were excluded based on *a priori* criteria. The mean age of the patients was 62.7 yr (range: 16–93 yr). There were 211 females (42.2%). The scans were performed for investigation of primary extra-thoracic disease in 62% of patients. The mean rotation of patients' chests on the scan table was 0.3 degrees (SD: 4.3) leftward rotation. Mediastinal shift was observed in 14 patients (2.8%).

In 264 CT scans [53%; 95% confidence interval (CI): 48–57%], some portion of a major vessel was anterior to the tracheal lumen at the suprasternal notch. Most commonly, this was the brachiocephalic artery or carotid artery (Table 1). In one

Table 1 Number of CT scans with the anterior–posterior projection of any major vessel overlapping the trachea at the suprasternal notch. *Includes CT scan of one patient with part of the aortic arch directly anterior to the trachea in the suprasternal notch. Note that the bifurcation of the brachiocephalic artery into right carotid and right subclavian arteries was above the suprasternal notch in 191 patients (38.2%)

| Vessel | Proportion of trachea overlapped by vessel | | |
|---|---|---|---|
| | Any | >25% | >50% |
| Brachiocephalic artery* | 167 (33.4%) | 138 (27.6%) | 80 (16.0%) |
| Right carotid artery | 90 (18.6%) | 42 (8.4%) | 16 (3.2%) |
| Left carotid artery | 47 (9.4%) | 4 (0.8%) | 1 (0.2%) |
| Left innominate vein | 32 (6.4%) | 22 (4.4%) | 17 (3.4%) |
| Right innominate vein | 1 (0.2%) | 0 (0%) | 0 (0%) |
| Total (any vessel) | 264 (52.8%) | 184 (36.8%) | 106 (21.1%) |

patient, it was the aortic arch. In two patients, the brachiocephalic trunk was entirely on the left of the trachea in the notch, and crossed the trachea horizontally above the suprasternal notch. Examples are shown in Fig. 1B–D.

The proportion of patients with major vessels anterior to the trachea decreased as the trachea ascended in the anterior triangle. Ten millimetres above the suprasternal notch, 126 scans (25%; 95% CI: 22–29%) had part of a major vessel anterior to the trachea, with 47 (9%) having more than half of the anterior tracheal border covered by a major vessel at this point. Twenty millimetres above the suprasternal notch, 48 scans (9%; 95% CI: 7.3–12.5%) had some part of the brachiocephalic artery or right carotid artery anterior to the trachea, and at 30 mm above the suprasternal notch, there were five patients (1%; 95% CI: 0.4–2.3%) with a major vessel anterior to the tracheal lumen. No scans had a major vessel anterior to the cricothyroid membrane.

No scans were observed with the combination of a short neck and high-riding major vessels. There were 23 patients (5%; 95% CI: 3.1–6.8%) with less than 10 mm between the suprasternal notch and the lower border of the thyroid membrane. None of these had a major vessel anterior to the trachea. Two patients (0.4%; 95% CI: 0.1–1.5%) had the lower border of their thyroid cartilage behind the manubrium.

It was not possible to estimate the length of the trachea in 33 scans, because 31 scans did not include the thyroid cartilage. A further two patients had a laryngectomy. In the remaining 467 patients, the length of the trachea was a mean of 112 mm (SD: 14.1). The mean length of the trachea above the suprasternal notch was 36.1 mm (SD: 16.2). The location of the suprasternal notch was variable, with the proportion of the trachea covered by the sternomanubrial ranging from 22% to 100% of the total length of the trachea [mean: 62%; interquartile range (IQR): 52–72%]. Patients who had a short distance between the suprasternal notch and thyroid cartilage were less likely to have an overlap of their cervical trachea by major vessels (Table 2).

Table 2 Number of CT scans with a major vessel anterior to the trachea in the suprasternal notch, categorised by distance between the suprasternal notch and thyroid cartilage

| Distance between suprasternal notch and thyroid cartilage (mm) | *n* | Number of patients with any major vessel anterior to the trachea in the suprasternal notch |
|---|---|---|
| Less than 25 | 120 | 10 (8%) |
| 25–35.9 | 133 | 56 (36%) |
| 36–48.9 | 131 | 94 (72%) |
| 50 or more | 116 | 108 (93%) |

At the suprasternal notch, the transverse luminal diameter of the trachea in females was 17.5 mm and in males was 19.8 mm. The apex of the aortic arch was a mean of 27.1 mm (13.9) inferior to the suprasternal notch. The point at which the brachiocephalic artery finished crossing the tracheal lumen was 62% (IQR: 57–68%) of the distance from the carina to the thyroid cartilage. The thyroid gland was wholly above the suprasternal notch in 319 patients, partly within the notch in 178 patients, and wholly intrathoracic in 2 patients.

## Structural abnormalities

Two patients (0.4%) had dextrocardia with a right aortic arch. Six patients (1.2%) had the right subclavian artery arising from

Table 3 Anatomical features associated with any overlap of the trachea in the suprasternal notch by major vessels (i.e. aorta, superior *vena cava*, innominate veins, right or left jugular veins, brachiocephalic trunk, and right or left carotid arteries). Smaller odds ratios indicate less chance of observing this abnormality. $n$=467, model $R^2$ is 0.47, log likelihood is −192, degrees of freedom: 17. This model excludes data from 33 scans where the superior extent of the scan was below the cricoid cartilage. *If this variable is replaced by the proportion of trachea above the suprasternal notch, then patients who have more than 44.4% of their trachea above the notch ($n$=158) have a relative risk of 5.30, $P$<00001, and patients with less than 32% of their trachea above the notch ($n$=155) have a relative risk of 0.07, $P$<00001, whilst the other variables in the model are substantially unchanged

| | *n* | Odds ratio | *P*-value |
|---|---|---|---|
| Male sex | 281 | 0.36 | 0.001 |
| Common carotid origin | 106 | 0.58 | 0.11 |
| Age (yr) | | | |
| <60 | 146 | 0.96 | 0.91 |
| >70 | 168 | 0.93 | 0.83 |
| Thoracic kyphosis | | | |
| <34.4 | 149 | 0.91 | 0.77 |
| >42.5 | 162 | 2.10 | 0.02 |
| Trachea diameter (mm) | | | |
| <17.8 | 155 | 0.40 | 0.009 |
| >20.1 | 161 | 2.21 | 0.01 |
| Trachea length (mm) | | | |
| <104.4 | 144 | 2.88 | 0.003 |
| >117.4 | 165 | 0.49 | 0.04 |
| Brachiocephalic artery origin: left of trachea (mm) | | | |
| <1 | 148 | 0.71 | 0.31 |
| >5.8 | 156 | 1.65 | 0.13 |
| Brachiocephalic artery origin: height above carina (mm) | | | |
| <27.5 | 143 | 1.22 | 0.55 |
| >35.0 | 159 | 1.38 | 0.34 |
| Length of trachea above suprasternal notch* (mm) | | | |
| <28.1 | 156 | 0.08 | <0.00001 |
| >42.3 | 156 | 14.7 | <0.00001 |

the distal aortic arch and passing behind the oesophagus into the right chest. Thirty patients (6.0%) had the left vertebral artery arising directly from the aortic arch. One hundred and six patients (21.2%) had a common origin of the brachiocephalic and carotid arteries.

Features associated with major vessels overlying the trachea in the suprasternal notch are described in Table 3. The proportion of total tracheal length above the suprasternal notch, or the length of trachea above the notch, was strongly associated with major vessels anterior to the tracheal lumen in the suprasternal notch (Table 3). There was a weak association of female sex with wide or short tracheas, and patients with increased thoracic kyphosis. We did not find significant associations with increasing age, brachiocephalic trunk origin, or presence of a common origin of the brachiocephalic and carotid arteries.

Fifty patient scans were subject to repeatability measurements; the mean correlation coefficient was 0.938. Fifty patient scans were subject to the test–retest procedure; the correlation coefficient was 0.858.

## Discussion

In a sample of 500 consecutive patients who had a thoracic CT scan for a variety of reasons, we found that more than half had a major vessel, most often the brachiocephalic artery, anterior to the trachea in the suprasternal notch. This has important implications for emergency front-of-neck airway access by clinicians without formal surgical training. Encountering such a major vessel during emergency airway access could result in extensive and potentially uncontrollable bleeding, making the airway access even more difficult and contributing to its own morbidity. Even 3 cm above the suprasternal notch, there remained a proportion of patients with part of a major vessel anterior to the trachea. In contrast, none of the patients had a major vessel anterior to the cricothyroid membrane. This supports a safety advantage of cricothyroidotomy over tracheostomy in emergency airway access, and emphasises the importance of accurately identifying the cricothyroid membrane.

Whilst we did not obtain a random sample of the population, it is unlikely that our sample was biased towards a higher prevalence of major vessels anterior to the trachea. None of the CT scans assessed were performed for the investigation of airway or anterior triangle vascular anomalies. They were performed for other indications, and were unselected and consecutive. In any event, it may not be possible to obtain a more random sample, because it would be unethical to subject a random sample of patients to a CT scan specifically for the purpose of the study. Therefore, until proven otherwise by a more valid technique, for safety reasons, a high proportion of major vessels anterior to the trachea must be assumed if emergency airway access is contemplated.

There are few systematic descriptions of the occurrence of major vessels anterior to the trachea in the root of the neck. Some large studies, including more than 12 000 patients in total, describe the prevalence of anomalies of the aortic arch and branches, but without detailing relationships with the trachea.[15–18] Badshah and colleagues[19] reported variability in vascular and tracheal anatomy relative to the vertebral level in 215 individuals, but did not make observations about the relation between major vessels and the trachea in the neck. In a recent study, Cai and colleagues[20] reported the results of 829 CT scans correlated with intraoperative observations during anterior cervical surgery in a Chinese population. They observed that the upper edge of the innominate artery was located above the suprasternal notch in 26.4% of patients, and in 2.1% of patients the innominate artery was anterior to the trachea midline 2 cm above the suprasternal notch; these are similar proportions to those we have observed in the present study. Farmery and colleagues[21] reported the location of the subclavian artery in relation to the cricoid cartilage in 50 adult patients undergoing MRI examination. They found that there was considerable variability in the distance between the subclavian arteries and the cricoid; also, a shorter length of the trachea above the clavicles was associated with closer proximity of the subclavian artery to the cricoid cartilage. Fawcett and colleagues[22] reported CT data on 100 children and 72 adults, finding the brachiocephalic trunk crossed the trachea above the suprasternal notch in 14 out of 48 children less than 3 yr old, but did not report the incidence of this in older children or adults.

Many authors have reported the presence of major vessels anterior to the trachea in the neck as a case report of a rare anomaly, for example, in association with tracheostomy,[6–10] mediastinoscopy,[11] thyroidectomy,[12] parathyroidectomy,[13] and thoracic surgery.[14] Our findings suggest that it is now time to recognise that this anomaly is much more common than previously anticipated.

We took the opportunity to investigate whether any clinical features were associated with a higher incidence of major vessels anterior to the trachea in an exploratory analysis using logistic regression. We found that most clinical features were not statistically significant predictors or were only weak predictors of this abnormality. This is a sobering observation, because it means that we can neither 'rule in' nor 'rule out' the presence of major vessels anterior to the neck based on standard clinical features. An exception was the association between the presence of major vessels anterior to the trachea in the anterior triangle and a long length of trachea above the suprasternal notch. If validated in subsequent studies, this could be a potentially useful predictor, because the length of trachea above the suprasternal notch should be easily appreciated by clinical examination.

We observed that only a small proportion of patients, around 5%, had less than 10 mm between their manubrium and larynx, and fewer than 1% had their cricothyroid membrane behind the manubrium. Fortunately, none of these patients also had high-riding major vessels, so it would appear that the combination of low-riding larynx and high-riding major vessels is uncommon.

Despite its observational nature, our study had several strengths. In particular, the aims were defined before data acquisition began, and we examined a large number of scans to give the study both high statistical power and precision. We also carefully validated our measurements with repeatability and test–retest measurements.

Nevertheless, there were several unavoidable weaknesses. The sample of patients we studied is likely to be biased towards those with chest disease, rather than being a representative sample of patients presenting to operating theatres or emergency departments. The patients were routinely imaged with a small pillow under their head: not dissimilar to the position used typically for induction of anaesthesia, but we did not examine whether patient posture (e.g. extending the neck) might influence the position of major neck vessels. There are little scientific data on the effect that neck extension has upon the head and neck vessels, so it is not clear if neck extension increases the exposure to the trachea alone, or to both trachea and accompanying vessels. There are also many smaller vessels that may be present anterior to the trachea, for example, the thyroid artery and veins, or the anterior jugular veins. These may cause bleeding complications, even in experienced hands.[23] We did not study these vessels for two reasons. Firstly, we could not be certain that our imaging techniques would reliably identify these small vessels, typically less than 4 mm in diameter.[24] Secondly, the consequences of damage to these vessels, which may be managed by ligature occlusion,[23] are quite different to those vessels that supply and drain the brain. Also, we did not examine vessels lateral to the trachea, which need to be treated with as much caution and care as those anterior to the trachea, on the basis that the presence of these vessels would be anticipated by medical practitioners as part of normal anatomy.

Why do some patients have major vessels anterior to the trachea in the anterior triangle? We can exclude any association with several patient factors; we observed little association with the age of the patient, the severity of thoracic kyphosis, the length of the trachea, the origin of the brachiocephalic artery, or the height of the aorta above the carina. Moreover, we found that the major vessels cross the trachea near its midpoint with little variation between patients. In contrast, we observed that the upper border of the manubrium varies considerably between patients: it may cover all of the trachea, or as little as 22%. We speculate that a high-placed manubrium consistently covers the point at which the major vessels cross the trachea, but that a low-placed manubrium does not. In this way, the variability in the location of the manubrium may be the main anatomical phenomenon that exposes major vessels anterior to the trachea. Whilst this hypothesis would be supported by our findings, it would require confirmation in subsequent studies.

The findings of our study have practical implications for all practitioners who may need to perform emergency percutaneous airway access. Major vessels are unlikely to be found anterior to the cricothyroid membrane, but some part of these vessels is likely to be anterior to the tracheal lumen in the lower part of the anterior triangle, in about 50% of patients, particularly in those with longer necks. The Difficult Airway Society recommends that preoperative examination of the neck should include ultrasonography if inspection and palpation do not identify the trachea and cricothyroid membrane.[25] We would go further than this and suggest that ultrasonography might be useful before front-of-neck access in all but the most dire emergency. Not only might ultrasound help identify the cricothyroid membrane,[26–28] but it may also identify major vessels, and thereby, help to reduce the risk of major vessel injury.

In conclusion, we have found that a major head and neck vessel may be found anterior to the trachea at sites where emergency airway access may be contemplated in a high proportion of patients. This is most likely in the suprasternal notch, where potentially about 50% of patients have part of a major vessel anterior to the trachea. In contrast, none of the CT scans in our study had a major vessel anterior to the cricothyroid membrane, and we observed no combinations of a low-riding larynx and high-riding major vessels. Further studies should be done to confirm these observations (e.g. by using ultrasound imaging), and to determine if this phenomenon can be modified by patient posture. In the meantime, until proven otherwise, clinicians attempting front-of-neck emergency airway should be prepared to encounter major vessels in the suprasternal notch in a high proportion of patients.

## Authors' contributions

Study design: both authors.
Data collection: W.M.W.
Data analysis: W.M.W.
Writing first draft: W.M.W.
Revising subsequent drafts: both authors.

## Acknowledgements

The authors wish to thank Dr Yi-Jin Kuok, radiologist, for advice on interpretation of the CT scans.

## Declaration of interest

The authors declare that they have no conflicts of interest.

## References

1. Apfelbaum JL, Hagberg CA, Caplan RA, Blitt CD, Connis RT, Nickinovich DG. Practice guidelines for management of the difficult airway. An updated report by the American Society of Anesthesiologists Task Force on management of the difficult airway. *Anesthesiology* 2013; **98**: 1269–77
2. Henderson JJ, Popat MT, Latto IP, Pearce AC. Difficult Airway Society guidelines for management of the unanticipated difficult intubation. *Anaesthesia* 2004; **59**: 675–94
3. Standring S, Borley NR, Collins P, et al. Pleura, lungs, trachea and bronchi. In: Standring S, editor. *Gray's anatomy*. 40th Edn. New York: Elsevier; 2008. p. 989–10006
4. Maruti Pol M, Gupta A, Kumar S, Mishra B. Innominate artery injury: a catastrophic complication of tracheostomy, operative procedure revisited. *BMJ Case Rep* 3 April 2014. https://doi.org/10.1136/bcr-2013-201628
5. McCormick B, Manara AR. Mortality from percutaneous dilatational tracheostomy. A report of three cases. *Anaesthesia* 2005; **60**: 490–5
6. Netzer A, Ostrovsky D, Bar R, Westerman ST, Golz A. Protection of high-riding aberrant innominate artery during open tracheotomy. *J Laryngol Otol* 2010; **124**: 892–5
7. Ozlugedik S, Ozcan M, Unal A, Yalcin F, Tezer MS. Surgical importance of highly located innominate artery in neck surgery. *Am J Otolaryngol* 2005; **26**: 330–2
8. Comert A, Comert E, Ozlugedik S, Kendir S, Tekdemir I. High-located aberrant innominate artery: an unusual cause of serious hemorrhage of percutaneous tracheotomy. *Am J Otolaryngol* 2004; **25**: 368–9
9. Mukadam GA, Hoskins E. Aberrant brachio-cephalic artery precluding placement of tracheostomy. *Anaesthesia* 2002; **57**: 297–8
10. Huempfner-Hierl H, Hierl T, Halama D. Rare anatomical variation of the brachiocephalic trunk encountered in tracheostomy. *Br J Oral Maxillofac Surg* 2017; **55**: 312–3
11. Upadhyay PK, Bertellotti R, Laeeq A, Sugimoto J. Beware of the aberrant innominate artery. *Ann Thorac Surg* 2008; **85**: 653–4
12. Gil-Carcedo E, Gil-Carcedo LM, Vallejo LA, Herrero D. High-riding innominate artery in neck surgery. *Acta Otorrinolarinol Esp* 2012; **63**: 396–8
13. Subasi ID, Yoruk O, Sipal S, Karakaya AD, Sengoz F. Brachiocephalic artery anomaly at the neck: importance

during minimally invasive video-assisted parathyroidectomy. *J Craniofac Surg* 2013; **24**: e571–2
14. Dua SG, Purandare NC, Pramesh CS. Incidental detection of high-riding innominate artery and bilateral retropharyngeal carotid arteries: radiological findings and clinical relevance. *Clin Radiol* 2011; **66**: 685–7
15. Katz JC, Chakravarti S, Ko HH, et al. Common origin of the innominate and carotid arteries, prevalence, nomenclature, and surgical implications. *J Am Soc Echocardiogr* 2006; **19**: 1446–8
16. Jakanani GC, Adair W. Frequency of variations in aortic arch anatomy depicted on multidetector CT. *Clin Radiol* 2010; **65**: 481–7
17. Uchino A, Saito N, Okada Y, et al. Variation of the origin of the left common carotid artery diagnosed by CT angiography. *Surg Radiol Anat* 2013; **35**: 339–42
18. Vučurević G, Marinković S, Puškaš L, et al. Anatomy and radiology of the variations of aortic arch branches in 1266 patients. *Folia Morphol (Warsz)* 2013; **72**: 113–22
19. Badshah M, Soames R, Khan MJ, Ibrahim M, Khan A. Revisiting thoracic surface anatomy in an adult population: a computed tomography evaluation of vertebral level. *Clin Anat* 2017; **30**: 227–36
20. Cai Q, Zhu H, Yu T, et al. Risk assessment of high-lying innominate artery with neck surgery. *Acta Otolaryngol* 2017; **137**: 315–9
21. Farmery AD, Shlugman D, Anslow P. How high do the subclavian arteries ascend into the neck? A population study using magnetic resonance imaging. *Br J Anaesth* 2003; **90**: 452–6
22. Fawcett SL, Gomez AC, Hughes JA, Set P. Anatomical variation in the position of the brachiocephalic trunk (innominate artery) with respect to the trachea: a computed tomography-based study and literature review of innominate artery compression syndrome. *Clin Anat* 2010; **23**: 61–9
23. Muhammad JK, Major E, Wood A, Patton DW. Percutaneous dilatational tracheostomy: haemorrhagic complications and the vascular anatomy of the anterior neck. A review based on 497 cases. *Int J Oral Maxillofac Surg* 2000; **29**: 217–22
24. Hatfield A, Bodenham A. Portable ultrasonic scanning of the anterior neck before percutaneous dilatational tracheostomy. *Anaesthesia* 1999; **54**: 660–3
25. Frerk C, Mitchell VS, McNarry AF, et al. Difficult Airway Society 2015 guidelines of management of unanticipated difficult intubation in adults. *Br J Anaesth* 2015; **115**: 827–48
26. Bertram S, Emshoff R, Norer B. Ultrasonographic anatomy of the anterior neck. Implications for tracheostomy. *J Oral Maxillofac Surg* 1995; **53**: 1420–4
27. Suzuki A, Iida T, Kunisawa T, Henderson JJ, Fujita S, Iwasaki H. Ultrasound-guided cannula cricothyroidotomy. *Anesthesiology* 2012; **117**: 1128
28. Kristensen MS, Teoh WH. Front of neck: continued discovery of this anatomy essential for airway management. *Br J Anaesth* 2018; **120**: 895–8

*Handling editor: T. Asai*