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Front of neck: continued discovery of this anatomy essential for airway management

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In this issue of *British Journal of Anaesthesia*, Gadd and colleagues[1] add small, but important, details to our knowledge of the anatomy of the front of the neck regarding the increased depth from the surface of the skin to the lumen of the trachea at the level of the cricothyroid membrane in the severely obese, and *how much deeper* we can expect it to be in the severely obese compared with in lean patients. Gadd and colleagues[1] studied third-trimester non-labouring parturients, and concluded that the cricothyroid membrane is indeed a deep structure in women of childbearing age with a high BMI. They studied a highly relevant patient group that has an increased risk of ending up in a situation where it is impossible to ventilate and intubate the trachea,[2] with ensuing necessity for emergency front-of-neck access to the airway. However, we do not know how well the findings in pregnant patients correspond to other patient categories, including males.

The clinician can benefit from these findings in several situations. In cases where the cricothyroid membrane is identified by inspection or palpation before induction of anaesthesia, it will allow the clinician to estimate the depth to the tracheal lumen; the same is the case when no previous attempt was made to identify the cricothyroid membrane. This knowledge could subsequently assist the clinician with accurate needle or scalpel insertion by achieving adequate depth for accessing the airway lumen, whilst avoiding an excessively deep insertion that could injure the posterior wall and lead to the creation of a false passage.[3] This could thus lead to an increased success rate with emergency cricothyrotomy, an increase that is highly needed, as the success rate with these procedures in the hands of anaesthetists has been disappointingly low.

Much has changed regarding our knowledge and handling of front-of-neck access since we have gained improved access to point-of-care ultrasonography (POCUS) of the airway. Before that era, imaging of the airway consisted mainly of occasional radiography or computed tomography (CT), whereas, now, anaesthetists themselves can produce real-time imaging.[4] It is logical to identify the cricothyroid membrane *before* the induction of anaesthesia[5]—just as no one would induce anaesthesia without at least evaluating the mouth opening. The identification of the cricothyroid membrane can often be done with inspection and or palpation, and if these methods fail, the cricothyroid membrane can be identified with ultrasonography. In the first scenario, where the cricothyroid membrane is identified with inspection or palpation, the findings reported by Gadd and colleagues[1] inform the anaesthesiologist of the thickness of tissues one must traverse in order to access the airway lumen, whereas ultrasonography can provide that information directly for the individual patient. If the clinician cannot identify the cricothyroid membrane, this information is valuable when it comes to deciding how to approach the airway, and will be a strong indicator that an awake approach should be considered because the escape, an emergency cricothyroidotomy, might be unsuccessful.

The ultrasound techniques used by Gadd and colleagues[1] have been shown to allow ultrasound-naive anaesthetists to successfully identify the cricothyroid membrane with a significantly greater accuracy in morbidly obese patients compared with palpation after a short course.[6,7] An important finding in the present study is that, for experienced ultrasonographers, the success rate for ultrasonographic identification of the cricothyroid membrane was 100%, even in the severely obese patients, and that the correlation was excellent between blinded ultrasonographers.

One might ask if identification of the cricothyroid membrane before cricothyrotomy matters? Can a longitudinal cut

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down to the cartilages not be made first and the problem solved? Pairaudeau and colleagues[8] found a 1% failure rate of cricothyroidotomy when the cricothyroid membrane was identifiable and a 3% failure rate when it was not identifiable in a simulation study. There was no significant difference in the failure rate, but this could be false negative (because of the insufficient number of patients studied to detect a difference of this magnitude). Additionally, the procedure was significantly faster[8] when the cricothyroid membrane was palpable. They utilised a model where the trachea was in the midline and not displaced, so that it was likely to be easy to see where to place a longitudinal cut. In reality, the trachea is not always midline, especially in patients with a haematoma, tumour, swelling, post-radiation therapy, etc., displacing the trachea. In these cases, the difference in success between an identified and an unidentified entry site to the airway is likely to be even greater.

Special considerations in the obstetric population

The women in the study by Gadd and colleagues[1] had a mean gestational age of 32–33 weeks. It is unknown, but possible, that the conditions might change further towards term, as it is known that Mallampati classifications worsen as pregnancy advances and even during the course of labour,[9,10] and that these changes extend to 48 h after delivery.[11] Compared with males, CT studies have shown that the cricothyroid membrane is not necessarily a superficial structure in women of childbearing age,[12] and consequently, may be difficult to palpate.[12] In pregnancy, breast enlargement and obesity can add to the difficulties in finding the cricothyroid membrane. Hence, using ultrasound for pre-anaesthetic identification of the cricothyroid membrane is a natural choice and superior to CT scans as it is devoid of any ionising radiation risk to mother and foetus.

Other roles for the cricothyroid membrane

The major importance of the cricothyroid membrane (Fig. 1) in airway management is to act as an entry port for emergency cricothyroidotomy, but it has several other roles, including injection of local anaesthetics in preparation for awake intubation and for needle/cannula insertion for oxygen insufflation during emergency airway management. Retrograde intubation is a well-described technique that uses the cricothyroid membrane, and should be maintained as part of the airway armamentarium for anaesthetists, as it is one of the few techniques that allow awake intubation with very limited, but ubiquitous, equipment, even in the bloody airway when the use of videolaryngoscopes and flexible fibrescopes can be useless because of soiling with the blood.[13]

Fig 1. "Looking through the front of the neck". Yellow is the cricothyroid membrane, orange the crico-tracheal membrane and red is the first interspace between tracheal rings, located between 1st and 2nd tracheal ring. Picture constructed by superimposing ultrasound picture on picture of the front of the neck (Figure used with permission from The Scandinavian Airway Management Course, www.airwaymanagement.dk)

A new use of the cricothyroid membrane is as a gateway to illuminate the airway with infrared light. When subsequent endoscopy is performed with a flexible videoscope, a blinking light seen emerging from the trachea[14] towards the operator can guide the insertion of the distal end of the flexible scope into the trachea. This is particularly helpful in cases of distorted anatomy.[15] This technique can also be used with a videolaryngoscope[16] provided that the video camera is able to detect the wavelength emitted by the infrared light source.

Other membranes for airway management at the front of the neck

The *hyothyroid membrane* between the lower border of the hyoid bone and the upper border of the thyroid cartilage does not provide access to the lower airway, but facilitates blocking of the superior laryngeal nerve for subsequent airway management. It is normally easily identified by palpation of the cornu of the hyoid bone, but ultrasonography can help identify the anatomy.[17]

The *cricotracheal membrane* ('cricotracheal ligament') is the interspace between the lower border of the cricoid cartilage and the upper border of the first tracheal ring (Fig. 1). When used as the entry point to the airway, it has the advantage that the distance to the vocal cords is greater than when using the cricothyroid membrane, thus diminishing the risk of injury to the vocal cords or of oesophageal intubation when used for retrograde intubation.[18] The cricotracheal membrane is located superficial in the airway just as the cricothyroid membrane, but it is narrower so it will not accommodate a normal-diameter tracheal tube. Also, the posterior part of the trachea may not be shielded by cartilage as it is when utilising the cricothyroid membrane, so caution should be taken not to penetrate the posterior wall. The risk of pneumothorax can be increased when utilising the cricotracheal membrane for airway access.

The *tracheal ring interspaces* (Fig. 1) are the entry ports for tracheotomy, with an open surgical technique or with needle/dilatational techniques. The trachea might not be easy to identify especially when it is not in the midline (e.g. infection, tumour, radiation therapy, or trauma), and in such cases, ultrasonography, applied immediately prior to airway access, might improve outcome by helping the clinician identify relevant structures and avoid overlying pathology and blood vessels.[19]

Role of ultrasonography in the ongoing discovery of the front of the neck

Surface ultrasonography has a dual role: (i) it can be used, as in the study by Gadd and colleagues,[1] to expand our knowledge

of the anatomy and pathology of the front of the neck and the rest of the upper airway; and (ii) most importantly, it can be used by the anaesthesiologist at the time of the clinical procedure itself. POCUS[4,19,20] allows the identification of the exact location of critical airway structures, and thus, supplements or substitutes older clinical techniques, such as palpation or aspirating air with a needle and a syringe in order to identify the trachea.

The possible use of point-of-care airway ultrasonography to identify the cricothyroid membrane in conjunction with airway management, but before inducing anaesthesia, has been adopted by several recent guidelines for airway management.[21–23] In recent guidelines on airway management in the critically ill,[21] concern is raised that markings placed on the skin relative to the cricothyroid membrane will move when positioning the patient for an emergency cricothyroidotomy. However, Mallin and colleagues[24] found that such marking reliably identified the cricothyroid membrane even after the manipulation of the head and neck as long as the head is placed back in the same extended-neck position as when the marking was made. This finding, plus the fact that the trachea might not be midline,[20] makes pre-procedural identification and marking of the cricothyroid membrane, if time permits, even more desirable.

POCUS[19] can be applied from the mouth to the pleura,[20] and has a long range of clinical indications, including pre-procedural evaluation of fasting status and real-time detection of oesophageal or main-stem bronchus intubation and of pneumothorax, and prediction of a difficult airway.[25] Additional roles are still being explored.[19,20]

Future steps in the discovery of the front of the neck

Can we extrapolate the findings by Gadd and colleagues[1] to severely obese non-parturients, to males, and to other patient categories? We suggest that future studies should investigate the depth from skin to lumen under the cricothyroid membrane in larger cohorts of patients over a greater weight/BMI range in both sexes. We also suggest a slight modification of the technique. Gadd and colleagues[1] recorded depth-to-luminal-air values by two different methods of contact between the ultrasound transducer and the skin: with firm pressure or with no pressure of the transducer against the skin (no pressure meaning that there is a visible layer of ultrasound gel under the transducer during the examination, indicating no pressure but acoustic contact). We think that, for clinically working anaesthetists and sonographers, the obvious approach is to use ultrasound gel and a light pressure that just assures contact between the transducer and the skin, but without deforming or compressing the underlying tissue. We would recommend this clinical approach also for future studies. Furthermore, there is a paucity of knowledge about airway dimensions in children, and this should be studied as well.[26]

Gadd and colleagues[1] used both a transverse and a longitudinal scan to determine the depth from skin to luminal air at the level of the cricothyroid membrane. For both clinical and research purposes, we advocate the longitudinal technique because it is the best documented[7] and because, in addition to revealing both the location and the depth of the cricothyroid membrane, it reveals this same information about the cricotracheal membrane and the interspaces between tracheal rings (i.e. structures that might all be used for subsequent airway management). Furthermore, the approach should be extended to explore and map the dimensions of, and depth to, the other airway-management-relevant structures in the front of the neck as outlined previously in relevant patient categories and weight groups. This will give the clinician knowledge about how best to approach these structures in case no ultrasound equipment is available for the procedure, or the skills or time for POCUS is lacking.

Authors' contributions

Editorial concept: both authors.
Literature search: M.S.K.
Supplementary literature search: W.H.T.
First version drafting: M.S.K.
Final manuscript writing: both authors.
Final version approval: both authors.
Agree to be accountable for all aspects of the work: both authors.

Declaration of interest

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Pre-hospital anaesthesia: no longer the 'poor relative' of high quality in-hospital emergency airway management

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The increased risks associated with emergency airway management performed outside the operating theatre are well documented.[1,2] Anaesthesia and advanced airway management in critically ill patients who present in the emergency department are recognised as a particular challenge and are associated with significant mortality and morbidity.[1] An increase in the delivery of physician-led pre-hospital emergency care in the UK and elsewhere has meant that a greater proportion of these patients have anaesthesia and critical airway interventions performed before arrival in hospital. Most pre-hospital airway management studies begin by outlining the increased difficulties of performing interventions well in the pre-hospital environment. However, as systems and the governance structures for pre-hospital emergency anaesthesia have evolved, and guidelines[3–5] have improved the consistency of practice, published results from high performing systems are increasingly impressive. They suggest that pre-hospital airway management may, for some measured performance indicators, be as effective as that in the emergency department and might even provide learning for improvement in in-hospital emergency airway care.

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