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REVIEW

Utility of ultrasound in airway management

W.H. Teoh [a,*], M.S. Kristensen [b]

[a] Duke-NUS Graduate Medical School Singapore, Department of Women's Anaesthesia, KK Women's & Children's Hospital, 100 Bukit Timah Road, Singapore 229899, Singapore

[b] Section for Anaesthesia for ENT-,Head-, Neck- and Maxillofacial Surgery, Centre of Head and Orthopaedics, Rigshospitalet, University Hospital of Copenhagen, Copenhagen, Denmark

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S U M M A R Y

The ultrasound probe in the hands of the anaesthesiologist represents a powerful new point-of-care tool for airway management. Ultrasound (US) can help anaesthesiologists locate the cricothyroid membrane before managing a difficult airway, rule out an intraoperative pneumothorax, locate the optimal level for elective dilatational tracheostomy, distinguish between tracheal and oesophageal intubation before initiation of ventilation, and help clinicians overcome many other challenges related to the upper and lower airways. Its utility in general surgical patients, pregnant females, the morbidly obese, paediatric, intensive care unit and prehospital retrieval patients are summarised. Indeed, the general availability of laptop-sized, easily transportable ultrasound machines combined with increasing familiarity with the use of this technology, now makes ultrasonography a fundamental tool in airway management.

1. Introduction

Results of the fourth National Audit Project (NAP 4) of the Royal College of Anaesthetists and the Difficult Airway Society of the United Kingdom confirm that inadequate airway management remains a major contributor to patient mortality and morbidity.[1] As such, any clinical tool that can improve airway management is a welcome adjunct to conventional clinical assessment.

Ultrasonography (US) is one such modality and has become an inherent point-of-care tool and part of the anaesthesiologists' armamentarium, prevalently used to guide vascular access and performance of regional nerve blocks. Therefore as ultrasound machines are now widely available in anaesthetizing locations, we anaesthesiologists should become familiar with their use—including for managing airways. The advantages of ultrasonography are plentiful: it is devoid of ionising radiation, rapid to perform, reproducible and repeatable, portable, widely available, and gives real-time dynamic images in the perioperative, anaesthesia and emergency settings. Several studies have established the role of ultrasonography and its utility in airway management in pre-empting and guiding clinical decision making, diagnosis and intervention in pathologies of both upper and lower airways.[2,3] For maximum benefit in airway diagnostics and management, ultrasonography should be used dynamically in real-time, by the treating clinician himself, in direct conjunction with both airway procedures and assessment of a patient with suspected pathology in the airways.

2. Airway ultrasonography

2.1. Equipment

Airway ultrasonography can be performed with a standard laptop sized US-machine. A standard linear high frequency probe (6–13 MHz), like the one most often used for regional anaesthesia and vascular access, will be sufficient for most airway sonography. For evaluation of the floor of mouth, base of tongue and prandial status, a convex "abdominal" low frequency probe (2–5 MHz) will be more suitable, and for lung and pleural examinations between two ribs, a micro-convex (5–8 MHz) probe is very convenient[3] (Fig. 1).

2.2. Ultrasound physics & airway anatomy: what can we depict with ultrasound?

Ultrasound refers to sound frequencies beyond 20,000 Hz with 2–15 MHz typically employed in medical imaging. Ultrasound does not penetrate air, so ultrasonography can only display the tissue from the skin and until the ultrasound-wave reaches the surface of the part of the airway that is most superficial, e.g. the posterior

* Corresponding author. Tel.: +65 63941081; fax: +65 62912661.

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Fig. 1. A portable laptop sized ultrasound machine with transducers useful in airway management. Left to right: A microconvex transducer (5–8 MHz), a curved convex low frequency (2–5 MHz) transducer, and a linear high-frequency (6–13 MHz) transducer.

surface of the root of the tongue, the mucosal lining of the anterior trachea or the pleura. When the US beam reaches air, a strong echo, in the form of a bright white line will appear. This line represents the "air–tissue border", (Fig. 2b) and everything beyond it is artefact, especially reverberation artefacts that create multiple parallel white lines on the screen. It is thus not possible to sonographically visualise the posterior trachea, posterior commissure, and posterior wall of the trachea by scanning from the surface of the anterior neck.

Different tissues have different acoustic impedance and sound reflection occurs at interfaces between different types of tissues. Fat and bone produce a strong echo resulting in *hyperechoic* white structures on US. Fluid collections or blood in vessels present little resistance to the US beam, generating little echo and result in *hypoechoic* black structures on the screen. When the US beam reaches bone, a strong hyperechoic (white line) appears, absorption of US energy ensues, resulting in acoustic shadowing that obscures nearly everything beyond the bone. Cartilaginous structures, such as the thyroid, the cricoid, and the trachea (Fig. 2a), appear homogeneously hypoechoic but tend to calcify with age. Muscles and connective tissue membranes are hypoechoic but appear more heterogeneously striated than cartilage. Glandular structures such as the submandibular and thyroid glands are homogeneous and mildly to strongly hyperechoic compared to nearby soft tissues. We have previously described, in easy-to-follow steps, how to visualise the airway from the tip of the chin until the mid-trachea with ultrasonography.[2] Table 1 lists airway structures of special interest that can be visualised on US. As the larynx is a superficial structure, US offers images of higher resolution then computed tomography (CT) or magnetic resonance imaging.[4] Studies exploring different modes of visualising and learning airway sonoanatomy have found a good concordance between ultrasonography and CT, and between ultrasonography and direct cadaveric dissection.[5]

2.3. *Overview of clinical applications*

2.3.1. *Preoperatively*

Ultrasound (US) can help anaesthesiologists in screening and predicting difficult laryngoscopy,[6] diagnosing pathology that can affect airway management prior to anaesthesia induction e.g. tumours in the neck, tongue, vallecula, pharynx or larynx, or a Zenker diverticulum that can pose an added aspiration risk.[7,8] Preoperative US can alert the clinician to avoid inserting laryngeal masks when sialolithiasis is present, as unilateral submandibular sialodenopathy can result,[9] and evaluate the magnitude and nature of stomach contents[10] to project if the surgery should be postponed if the risk of aspiration outweighs the risk of proceeding. The cricothyroid membrane can be located ultrasonographically and marked out *prior* to managing a difficult airway,[2] thereby allowing preparation for oxygen insufflation, instillation of local anaesthetics, retrograde intubation or emergency cricothyroidotomy should the need arise. US can also aid visualisation of the superior laryngeal nerve, and injection of local anaesthetics, for airway blocks.[11]

2.3.2. *Intraoperatively*

US can be used to guide selection of appropriately sized tracheal tubes based on the measured diameter of the subglottic upper airway[12] and predict the size of left-sided double lumen tubes[13] whereby the ratio between left main-stem bronchus diameter on CT-imaging and outer tracheal diameter measured with US was 0.68, and these results were found to be comparable with those obtained using chest radiograph. US can be used to distinguish

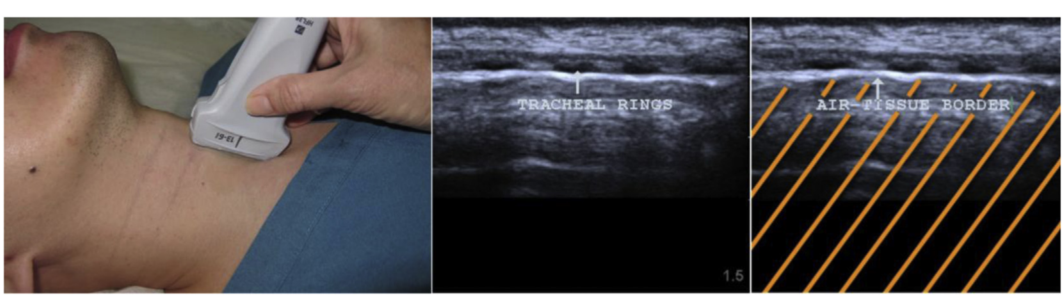

Fig. 2. The ultrasonographic image of the anterior neck depicting the anterior part of the tracheal rings, seen as hypoechoic black round structures, and the "air–tissue border" between the mucosal lining of the anterior trachea and air, seen as a hyperechoic white line. The image area posterior to it is entirely made up of artefacts (orange lines). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)