BJA

British Journal of Anaesthesia, 120 (5): 1033–1039 (2018)

doi: 10.1016/j.bja.2018.02.010
Advance Access Publication Date: 21 March 2018
Obstetrics

OBSTETRICS

Relationship between severe obesity and depth to the cricothyroid membrane in third-trimester non-labouring parturients: a prospective observational study

K. Gadd[1,2,*], K. Wills[3], R. Harle[4] and N. Terblanche[3,5]

[1]Department of Anaesthesia, Launceston General Hospital, Launceston, Australia, [2]Launceston Clinical School, University of Tasmania, Launceston, Australia, [3]Menzies Institute for Medical Research, University of Tasmania, Hobart, Australia, [4]Department of Medical Imaging, Royal Hobart Hospital, Hobart, Australia and [5]Department of Anaesthesia and Perioperative Medicine, Royal Hobart Hospital, Hobart, Australia

*Corresponding author. E-mail: karl.gadd@ths.tas.gov.au

This article is accompanied by an editorial: Front of neck: continued discovery of this anatomy essential for airway management by Kristensen & Teoh, *Br J Anesth* 2018:120:895-898, doi: 10.1016/j.bja.2018.02.015.

Abstract

Background: Severely obese parturients have increased 'cannot intubate, cannot oxygenate' risk during Caesarean section under general anaesthesia. Front-of-neck access (FONA) at the cricothyroid membrane (CTM) is definitive management; however, attempted FONA can fail. Point-of-care ultrasonography may provide useful information about CTM depth to aid FONA in obesity. This study determined the difference in CTM depth between severely obese and non-obese parturients, utilising ultrasonography.

Methods: In this prospective observational study, two anaesthetists performed airway ultrasonography on 15 severely obese (BMI >45 kg m^{-2}) and 15 normal-weight (BMI ≤25 kg m^{-2}) parturients in the third trimester, using the transverse and longitudinal planes, sniffing and extended head positions, and nil and firm transducer pressures. The primary outcome was CTM depth (millimetres) measured in the transverse plane with the head extended and nil transducer pressure. Secondary outcomes included CTM depth measurements using other factor configurations. Intra-class correlation coefficients assessed the inter-observer reliability.

Results: CTM depth measured in the transverse plane with head extended and nil transducer pressure was significantly greater in severely obese parturients, mean 18.0 mm (95% confidence interval 16.3–19.8), *vs* 10.6 mm (8.81–12.4) in non-obese (P<0.001); mean difference 7.4 mm (4.9–9.9; P<0.001). CTM depths were increased in the severely obese group regardless of scanning plane, head and neck position, or transducer pressure (all P<0.001). There was excellent inter-observer reliability.

Conclusions: Cricothyroid membrane depth is significantly increased in severely obese *vs* normal-weight parturients independently of scanning plane, head and neck position, or transducer pressure.

Keywords: airway management; intubation; oxygen inhalation therapy; pregnancy; ultrasonography

Editorial decision: February 12, 2018; **Accepted:** February 12, 2018

© 2018 British Journal of Anaesthesia. Published by Elsevier Ltd. All rights reserved.
For Permissions, please email: permissions@elsevier.com

Editor's key points

- In the situation of 'cannot intubate, cannot oxygenate', front-of-neck access may be required, but identification of the cricothyroid membrane can be difficult in obese pregnant women.
- Front-of-neck access might be more difficult in severely obese pregnant women since the cricothyroid membrane is deeper from the skin than in lean pregnant women.

Front-of-neck access (FONA) to the airway, also known as surgical airway access, is definitive management for 'cannot intubate, cannot oxygenate' (CICO) events.[1] However, success can be variable, particularly in obese parturients where percutaneous devices can be inadequate in length or kink.[1–3] Airway guidelines of the Obstetric Anaesthetists' Association therefore recommend all parturients to undergo assessment to predict potential FONA difficulty.[1] As anaesthetists have poor accuracy with localisation of the cricothyroid membrane (CTM) by palpation for this assessment in obesity, ultrasonography is useful.[1,4,5] Given the overlying soft tissues of the larynx have varying proportions, ultrasonography could additionally provide valuable information at the point of care regarding CTM depth in severely obese parturients.[4]

Although it is recognised that the CTM is deeper in obese than non-obese patients, the difference in CTM depth between severely obese and normal-weight parturients has not been quantified.[4] This further information may be useful to plan needle or scalpel insertion if emergency FONA is required. We sought to quantify, using ultrasonography, if CTM depth, the distance between the skin and the CTM's air–tissue border, is significantly greater in severely obese compared with normal-weight parturients, using different scanning planes, head and neck positions, and transducer pressures.

Methods

Study design

After receiving the University of Tasmania Human Research Ethics Committee's approval (H0014787), a prospective observational study was performed at the Royal Hobart Hospital between July 2015 and February 2016. Written informed consent was obtained from all participants. The study protocol and reporting were according to the Strengthening the Reporting of Observational Studies in Epidemiology statement.[6]

Participants

Parturients in their third trimester were recruited at the Women's Services Clinic and the Obstetric Ward at the Royal Hobart Hospital. The inclusion criteria were age over 18 yr, gestation over 30 weeks, and either severe obesity with BMI >45 kg m^{-2} or normal weight with BMI $\leq$25 kg m^{-2}. Every eligible severely obese parturient was approached for recruitment during the study period. The recruitment of every eligible normal-weight parturient was impractical because of the high frequency of eligible patients; therefore, they were recruited by convenience sampling. The exclusion criterion was abnormal neck anatomy affecting the airway.

Study procedures

The study participants' height (metres) and weight (kilograms) were measured immediately before the ultrasound examinations and the BMI (kilograms per metre squared) was calculated. Whilst the participants were seated, their neck circumference (centimetres) was measured with a tape measure by an experienced anaesthetist infraglottically, just below the level of the larynx, keeping the tape taut with the skin circumferentially whilst the measurement was performed.

Ultrasonography procedures were standardised for all women and performed at the Women's Services Clinic and the Obstetric Ward at the Royal Hobart Hospital, using a SonoSite X-Porte™ (Brookvale, NSW, Australia) ultrasound machine with a 13–6 MHz (HFL38XP) linear transducer. The same two anaesthetists performed all scans and ultrasound measurements, and are from here on referred to as ultrasonographers. To reduce bias, each ultrasonographer had at least 5 yr experience with ultrasonography in clinical practice and performed a minimum of 20 infraglottic airway ultrasound examinations on non-study patients before the study recruitment.

Each participant's scans were performed using the same positioning in quick succession on a single day. A small wedge was placed for the duration of scanning under the right pelvis to provide left lateral tilt to prevent aortocaval compression. For scans performed with nil transducer pressure, the ultrasound gel had to be visible on the scanning image between the transducer and the participant's skin to ensure that the least amount of pressure possible was applied.

Ultrasonography in the transverse plane

For airway ultrasonography, the participants were initially positioned supine, in the sniffing position with their head on a pillow. The ultrasonographers stood to the participants' left, with the transducer held in their left hand. Both anaesthetists were present for initial ultrasound scanning to identify the CTM in the transverse plane. The presence of a bright hyperechoic line indicated the CTM's air–tissue border. The CTM's air–tissue border was located between the thyroid cartilage (overlying the vocal cords) proximally and the cricoid cartilage distally.[7,8] The transverse level of the CTM was then marked on the participant's skin using ultrasonography.

Each ultrasonographer, blinded to the other's CTM depth measurements, then independently performed transverse-plane scanning at the marked level using both nil and firm transducer pressures. The order of the ultrasonographers performing the scans was not randomised, as they took it in turns to be the first to perform the scans on any given parturient. The CTM depth measurements were captured on the scans using the inbuilt calipers of the machine. This process was repeated with the participants' heads in the extended position, by removing the pillow from under their heads. Figure 1 depicts a transverse-plane sonogram using nil transducer pressure in a severely obese parturient.

Ultrasonography in the longitudinal plane

For scanning in the longitudinal plane, the two ultrasonographers were no longer blinded to assist each other because of the increased difficulty of scanning in this plane. The scans were performed with the head in the extended position only, using both nil and firm transducer pressures. Using a modified

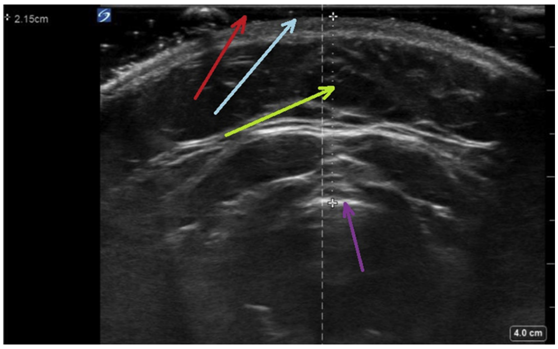

Fig 1. Scan in the transverse plane using nil transducer pressure, BMI >45 kg m^{-2}. Red arrow, ultrasound gel (between transducer and skin); blue arrow, skin; green arrow, caliper marking the CTM depth, with a depth of 21.5 mm; and purple arrow, air–tissue border of the CTM. CTM, cricothyroid membrane.

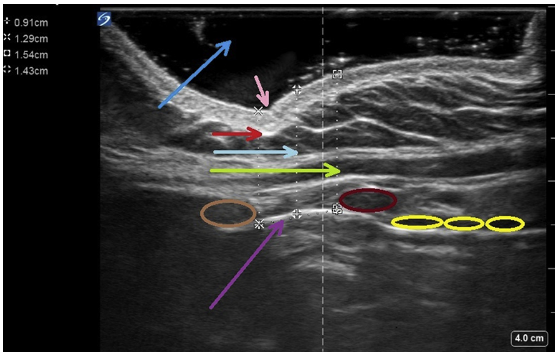

Fig 2. Scan in the longitudinal plane using no transducer pressure, BMI >45 kg m^{-2}. Note skinfold near CTM area. Dark blue arrow, ultrasound gel (between transducer and skin); red arrow, caliper marking the CTM depth at the proximal endpoint of the CTM, measured to the air–tissue border of the CTM, with a depth of 12.9 mm; light blue arrow, caliper marking the CTM depth at the midpoint of the CTM, measured to the air–tissue border of the CTM, with a depth of 14.3 mm; green arrow, caliper marking the CTM depth at the distal endpoint of the CTM, measured to the air–tissue border of the CTM, with a depth of 15.4 mm; purple arrow, caliper marking the CTM length, measured along the air–tissue border of the CTM, with a length of 9.1 mm; pink arrow, position of a skinfold in the anterior neck; brown ring, thyroid cartilage; burgundy ring, cricoid cartilage; and yellow rings, tracheal rings (the 'string of pearls').[9,10] CTM, cricothyroid membrane.

'string of pearls' technique, the transducer was placed longitudinally directly over the anterior airway in the midline, with its midpoint near the skin marking of the transverse position of the CTM, and then the transducer position was adjusted until the thyroid cartilage, CTM's air–tissue border, and cricoid cartilage were simultaneously visualised, whilst positioning the transducer at right angles to the anterior airway.[9,10] The CTM depth measurements were then marked using the inbuilt callipers of the machine at three locations along its length: at the proximal endpoint, midpoint, and distal endpoint of the CTM's air–tissue border. Also, using longitudinal ultrasonography, the CTM length (millimetres) was measured longitudinally from the proximal to the distal endpoints of the CTM's air–tissue border. Each longitudinal scan was saved with and without markings. Unmarked scans were later independently reviewed by a radiologist using Philips iSite™ (version 4.1, 2011, North Ryde, NSW, Australia) picture archiving and communications software to measure the same three CTM depths and the CTM length for comparison. Figure 2 depicts a sonogram of a longitudinal scan using nil transducer pressure in a severely obese parturient.

Primary outcome

The CTM depth (millimetres) is defined as the percutaneous distance between the skin and the CTM's air–tissue border in the midline. For the primary outcome, the CTM depth was measured ultrasonographically in the transverse plane with the head in the extended position and using nil transducer pressure.

Secondary outcomes

The CTM depth (millimetres) was also measured in the transverse plane with the head in the extended position and using firm transducer pressure; in the sniffing position with both nil and firm transducer pressures; and, lastly, in the longitudinal plane with the head extended, and using both nil and firm transducer pressures. The CTM depth in the longitudinal plane was measured at three locations along the CTM longitudinal midline, at the proximal endpoint, midpoint, and distal endpoint (see Fig 2). Also, using longitudinal ultrasonography, the CTM length was measured from the proximal to the distal endpoints, and the presence of skinfolds overlying the airway was recorded (see Fig. 2). Additionally, the relationship of the CTM depth to the neck circumference was determined.

Statistical analysis

Sample-size calculation was based on data from an observational study that reported the mean CTM depth 13.69 mm (SD 3.46 mm) in cadavers with mixed body habitus, with a margin of 5 mm between severely obese and normal-weight parturients assumed to be clinically significant.[11] Using a two-sample *t*-test (two sided), with β=0.10 and α=0.05, 11 patients were required for each group to detect a difference of 5 mm or more.

Linear mixed models were used to estimate the difference in CTM depths and lengths between the severely obese and normal-weight parturients. We compared the CTM depths measured using nil or firm transducer pressure by including two additional fixed effects in the model: pressure (nil or firm) and an interaction term for the BMI group and pressure to estimate the difference between the groups. Random intercepts were specified for subjects to account for dependence in repeated measurements on the same person by different observers.

Intra-class correlation coefficients (ICCs) and 95% confidence intervals (95% CIs) were calculated to estimate the agreement between the observers' measurements of CTM depth and the length. ICCs were determined using a two-way mixed effects model for absolute agreement. This corresponds to the ICC (2,1) model[12] and the ICC (C,1) model.[13] All statistical analyses were performed using the statistical software package Stata™ version 12, 2011 (StataCorp, College Station, Texas, USA).

The relationship of CTM depth to neck circumference was determined visually using a scatter plot with a locally weighted scatter-plot smoothing regression curve. A regression model was not used for this because of the nature of the study sample having two discrete BMI groups rather than a random sample from the population of interest.

Results

Participant characteristics

Figure 3 illustrates the study enrolment and participant flow. Table 1 presents the characteristics of the study participants. The mean age and gestation at the time of each participant booking into the obstetric clinic were similar for women in the severely obese and normal-weight groups. Table 2 shows linear mixed model estimates for mean CTM depths and lengths for severely obese and normal-weight parturients, and ICCs for the agreement between the observers' measurements.

Primary outcome

The CTM depth was significantly increased in severely obese compared with normal-weight parturients using transverse-plane scanning in the extended head position with nil transducer pressure (Table 2). The ICC for these measurements indicated excellent inter-observer reliability.

Table 1 Baseline characteristics of normal-weight (n=15) and severely obese (n=15) parturients in their third trimester. Values are mean (SD). SD, standard deviation

Variable	Normal weight, BMI ≤25 kg m^{-2}		Severe obesity, BMI >45 kg m^{-2}	
	Mean (SD)	Range	Mean (SD)	Range
Age (yr)	29.5 (5.4)	19–25	28.8 (5.5)	20–39
Gestation (weeks)	32.2 (2.3)	30–37	33.8 (2.5)	30–39
Weight (kg)	56.4 (8.1)	44–71	132.8 (17.1)	113–166
BMI (kg m^{-2})	21.5 (1.8)	19–25	50.8 (3.3)	46–57

Secondary outcomes

Table 2 also shows that the CTM depth was significantly increased in the severely obese group independent of ultrasound scanning plane, head and neck positions, transducer pressure, or the longitudinal position along the CTM midline where the depth was measured. Ultrasonography using firm pressure significantly reduced the mean CTM depth for the normal-weight group by 4.5 mm (95% CI 5.2–3.7; P<0.001), and by a further 4.0 mm (5.1–2.9; P<0.001) for the severely obese group, compared with scanning with nil pressure. Even so, the mean increase in CTM depth in the severely obese group, whilst using firm transducer pressure, remained significant (P<0.001). The ICCs for all CTM depth measurements indicated excellent inter-observer reliability.

The CTM depth had a close linear relationship with the neck circumference, particularly for the normal-weight group

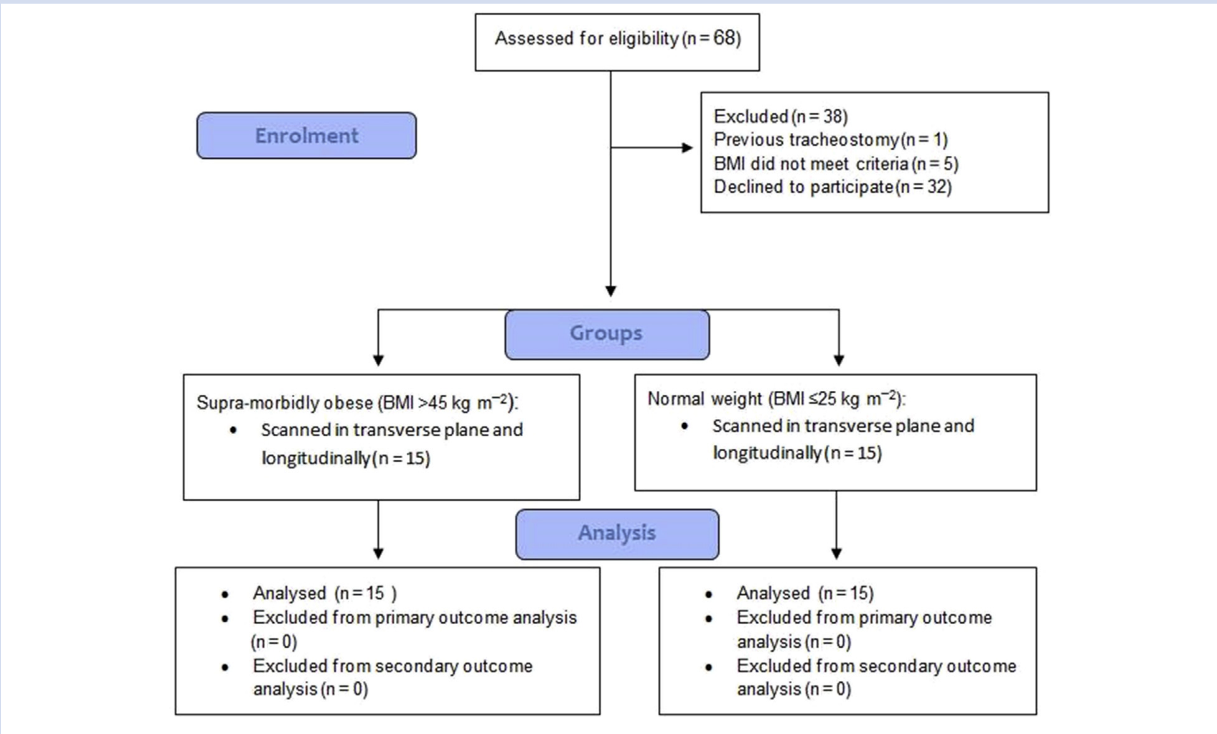

Fig 3. Enrolment and allocation of participants in the study.

Table 2 Intra-class correlation coefficients with 95% CIs, and estimated means and differences with 95% CIs, for cricothyroid membrane depths and lengths for severely obese (n=15) and normal-weight parturients (n=15)

	Inter-rater reliability		Normal weight, BMI ≤25 kg m^{-2}		Severe obesity, BMI >45 kg m^{-2}		Difference between BMI groups		
	ICC	(95% CI)	Mean (mm)	(95% CI)	Mean (mm)	(95% CI)	Mean (mm)	(95% CI)	P-value
Transverse plane									
Nil transducer pressure									
Airway in extended position	0.98	(0.95–0.99)	10.6	(8.8–12.4)	18.0	(16.3–19.8)	7.4	(4.9–9.9)	<0.001
Airway in sniffing position	0.89	(0.79–0.95)	10.9	(9.4–12.4)	17.7	(16.2–19.2)	6.8	(4.6–9.0)	<0.001
Firm transducer pressure									
Airway in extended position	0.86	(0.68–0.93)	6.1	(5.2–7.1)	9.6	(8.7–10.5)	3.4	(2.1–4.7)	<0.001
Airway in sniffing position	0.92	(0.80–0.96)	6.0	(5.1–6.9)	9.5	(8.7–10.4)	3.5	(2.3–4.8)	<0.001
Longitudinal (extended position)									
Nil transducer pressure									
Proximal point of CTM	0.98	(0.95–0.99)	11.2	(9.6–12.8)	16.4	(14.8–18.0)	5.2	(3.0–7.4)	<0.001
Midpoint of CTM	0.99	(0.98–0.995)	10.6	(9.2–12.1)	17.0	(15.5–18.5)	6.4	(4.3–8.4)	<0.001
Distal point of CTM	0.99	(0.98–0.995)	10.4	(9.0–11.9)	18.5	(17.0–19.9)	8.1	(6.0–10.1)	<0.001
Length of CTM	0.63	(0.10–0.84)	9.1	(8.5–9.7)	9.4	(8.8–10.0)	0.3	(−0.6 to 1.2)	0.488
Firm transducer pressure									
Proximal point of CTM	0.97	(0.94–0.99)	7.6	(6.5–8.7)	12.5	(11.4–13.5)	4.9	(3.4–6.4)	<0.001
Midpoint of CTM	0.98	(0.95–0.99)	7.0	(5.8–8.1)	12.3	(11.2–13.4)	5.3	(3.7–6.9)	<0.001
Distal point of CTM	0.96	(0.92–0.98)	6.5	(5.2–7.8)	12.0	(10.7–13.3)	5.5	(3.7–7.4)	<0.001
Length of CTM	0.60	(0.19–0.81)	9.3	(8.5–10)	9.9	(9.2–10.6)	0.6	(−0.4 to 1.7)	0.244

CI, confidence interval; CTM, cricothyroid membrane; ICC, intra-class correlation coefficient.

(Fig. 4). Transverse, anterior neck skinfolds overlying the airway anteriorly at or near the CTM were found on longitudinal scanning in 73% (11/15) of severely obese, but not at all in normal-weight, parturients.

Discussion

The principal finding of this study was that CTM depth is significantly increased in severely obese compared with normal-weight parturients independent of the plane of ultrasound scanning, position of the airway, transducer pressure, or longitudinal position along the CTM where the depth was measured.

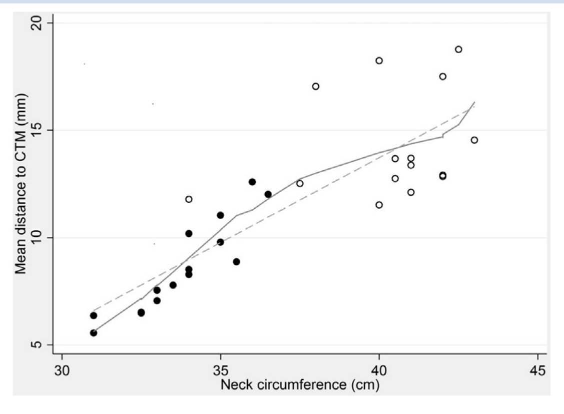

Fig 4. Scatter plot of cricothyroid membrane depth (mm) and neck circumference (cm), with both the linear fit and LOWESS curve shown, correlation coefficient r=0.8408 (95% CI 0.71–0.92). Solid dots are normal-weight parturients; hollow dots are severely obese parturients. CTM, cricothyroid membrane; LOWESS, locally weighted scatter-plot smoothing.

To our knowledge, this is the first study in an obstetric population to assess the CTM depth using ultrasonography, and to calculate the difference in this depth between severely obese and normal-weight parturients. A retrospective study of 18 females of childbearing age, but not pregnant, and of mixed body habitus, demonstrated that the mean (range) of CTM depth was 16.2 mm (3–18) when measured with computed tomography.[4] It also found significant correlation between CTM depth and BMI (P=0.04).[4] Those findings are consistent with our data that suggest that the CTM is a deep structure in women of childbearing age with a high BMI.[4] Our study additionally provides useful quantitative information about the CTM depth in severely obese parturients that could aid airway planning and management.

Anaesthetists are inaccurate at localisation of the CTM using landmark palpation, particularly in obese females, including parturients.[5,14–17] Increased CTM depth explains why its localisation by landmark palpation was less accurate in obese when compared with normal-weight parturients.[5] It explains why localisation of the CTM by ultrasound guidance was more accurate in an obese patient when compared with landmark palpation.[18] Substantial subcutaneous fatty tissue increases the CTM depth in severely obese parturients and reduces the definition of deeper cartilaginous airway structures to the clinician's tactile sense, whereas ultrasound image quality is only minimally affected.[4,5,10,16–18] This study shows that the CTM can be localised and its depth measured ultrasonographically in severely obese parturients, with excellent agreement between blinded ultrasonographers.

Severely obese parturients are at higher risk of failed intubation that could lead to a CICO event during general anaesthesia for Caesarean section.[3,19–22] A brief pre-procedural ultrasound examination of the anterior airway, which includes localisation, and assessment of the depth, of the CTM may aid airway management in severely obese parturients, especially those with suspected difficult intubation. For FONA procedures, information on CTM depth could assist with accurate needle or scalpel insertion to achieve adequate depth for accessing the airway lumen, whilst avoiding excessively deep insertion that could iatrogenically injure the posterior wall and lead to the creation of a false passage.[23,24] Because of the potential for severe consequences from any CICO event, the ability to perform pre-procedural ultrasound examination of the infraglottic airway does not exonerate the anaesthetist from having standard equipment ready to proceed with FONA if required, and regular training for it. Measurement of CTM depth using ultrasound may advance FONA training and research, specifically through simulation because of the low occurrence of emergency FONA in clinical anaesthesia.[3,25]

Limitations

There is a potential for the introduction of confirmation bias, as measurements of CTM depth and length using ultrasound were not compared with a gold standard. However, this is unlikely to be significant, as other studies have shown that ultrasound measurements of the upper airway in the neck region have correlated well with computed tomography[26] and magnetic resonance imaging.[27] Transducer pressure was not measured during firm pressure scanning to ensure that both blinded ultrasonographers applied pressure similarly to avoid measurement bias; nevertheless, reliability remained excellent. Transverse scans were not necessarily performed at the CTM's midpoint, possibly introducing measurement bias, although the effect would have been minimal given that, whilst using scanning in the longitudinal plane, CTM depths intentionally measured at three different longitudinal points along the midline did not display substantial variation. Although the sample size was small, we had a strong anatomical rationale for expecting an increased CTM depth and we pre-specified the direction of the association.

Conclusions

This study found that, in severely obese parturients, the cricothyroid membrane is a significantly deeper anatomical structure when compared with normal-weight parturients. Given that severely obese women are at higher risk of failed tracheal intubations during general anaesthesia for Caesarean section that can potentially deteriorate to cannot intubate, cannot oxygenate events requiring front-of-neck access, the findings in this study prepare clinicians to make a correspondingly deeper needle or scalpel insertion if required to perform emergency front-of-neck access, thus possibly increasing the success rate of the procedure.[3,19–22]

Authors' contributions

Study conception: N.T.
Study design: all authors.
Ethics committee application: K.G., N.T.
Participant recruitment: K.G., N.T.
Blinded observation: K.G., N.T.
Independent observation: R.H.
Data collection: K.G., R.H., N.T.
Data analysis: K.W., N.T.
Data interpretation: K.W., N.T.
Manuscript writing: all authors.
Final manuscript approval: all authors.

Declaration of interest

The authors have no conflict of interest to declare.

Funding

External funding including grants did not support this work. The Tasmanian Health Service and the University of Tasmania supported this work with all researchers involved being paid as part of their usual salaried employment at their respective institutions. Equipment and facilities used in the project were provided by the Royal Hobart Hospital.

Acknowledgements

The authors are grateful to Dr Adam Mahoney for his assistance with the literature review to prepare the study protocol, Ms Sandy Hanon who aided with the preparation and scanning of documents, and Dr Savas Totonidis for giving his advice on planning the study goals.

References

1. Mushambi MC, Kinsella SM, Popat M, et al. Obstetric Anaesthetists' Association and Difficult Airway Society guidelines for the management of difficult and failed tracheal intubation in obstetrics. *Anaesthesia* 2015; **70**: 1286–306
2. Apfelbaum JL, Hagberg CA, Caplan RA, et al. 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; **118**: 251–70
3. Cook T, Woodall N, Frerk C. *4th National Audit Project of the Royal College of Anaesthetists and the difficult Airway Society: Major complications of airway management in the United Kingdom*. London: Report and findings; 2011
4. Long N, Ng S, Donnelly G, et al. Anatomical characterisation of the cricothyroid membrane in females of childbearing age using computed tomography. *Int J Obstet Anesth* 2014; **23**: 29–34
5. You-Ten KE, Desai D, Postonogova T, Siddiqui N. Accuracy of conventional digital palpation and ultrasound of the cricothyroid membrane in obese women in labour. *Anaesthesia* 2015; **70**: 1230–4
6. Von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol* 2008; **61**: 344–9
7. Kristensen MS, Teoh WH, Graumann O, Laursen CB. Ultrasonography for clinical decision-making and intervention in airway management: from the mouth to the lungs and pleurae. *Insights Imaging* 2014; **5**: 253–79
8. De Oliveira Jr GS, Fitzgerald P, Kendall M. Ultrasound-assisted translaryngeal block for awake fibreoptic intubation. *Can J Anaesth* 2011; **58**: 664–5
9. Kristensen MS. Ultrasonography in the management of the airway. *Acta Anaesthesiol Scand* 2011; **55**: 1155–73
10. Kristensen MS, Teoh WH, Rudolph SS, Hesselfeldt R, Borglum J, Tvede MF. A randomised cross-over comparison of the transverse and longitudinal techniques for

ultrasound-guided identification of the cricothyroid membrane in morbidly obese subjects. *Anaesthesia* 2016; **71**: 675–83
11. Bennett JD, Guha SC, Sankar AB. Cricothyrotomy: the anatomical basis. *J R Coll Surg Edinb* 1996; **41**: 57–60
12. Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. *Psychol Bull* 1979; **86**: 420–8
13. McGraw KO, Wong SP. Forming inferences about some intraclass correlation coefficients. *Psychol Methods* 1996; **1**: 30–46
14. Hiller KN, Karni RJ, Cai C, Holcomb JB, Hagberg CA. Comparing success rates of anesthesia providers versus trauma surgeons in their use of palpation to identify the cricothyroid membrane in female subjects: a prospective observational study. *Can J Anaesth* 2016; **63**: 807–17
15. Elliott DS, Baker PA, Scott MR, Birch CW, Thompson JM. Accuracy of surface landmark identification for cannula cricothyroidotomy. *Anaesthesia* 2010; **65**: 889–94
16. Lamb A, Zhang J, Hung O, et al. Accuracy of identifying the cricothyroid membrane by anesthesia trainees and staff in a Canadian institution. *Can J Anaesth* 2015; **62**: 495–503
17. Aslani A, Ng SC, Hurley M, McCarthy KF, McNicholas M, McCaul CL. Accuracy of identification of the cricothyroid membrane in female subjects using palpation: an observational study. *Anesth Analg* 2012; **114**: 987–92
18. Kristensen MS, Teoh WH, Rudolph SS, et al. Structured approach to ultrasound-guided identification of the cricothyroid membrane: a randomized comparison with the palpation method in the morbidly obese. *Br J Anaesth* 2015; **114**: 1003–4
19. Quinn AC, Milne D, Columb M, Gorton H, Knight M. Failed tracheal intubation in obstetric anaesthesia: 2 yr national case-control study in the UK. *Br J Anaesth* 2013; **110**: 74–80
20. Hood DD, Dewan DM. Anesthetic and obstetric outcome in morbidly obese parturients. *Anesthesiology* 1993; **79**: 1210–8
21. Tonidandel A, Booth J, D'Angelo R, Harris L, Tonidandel S. Anesthetic and obstetric outcomes in morbidly obese parturients: a 20-year follow-up retrospective cohort study. *Int J Obstet Anesth* 2014; **23**: 357–64
22. Kinsella SM, Winton AL, Mushambi MC, et al. Failed tracheal intubation during obstetric general anaesthesia: a literature review. *Int J Obstet Anesth* 2015; **24**: 356–74
23. Siddiqui N, Arzola C, Friedman Z, Guerina L, You-Ten KE. Ultrasound improves cricothyrotomy success in cadavers with poorly defined neck anatomy: a randomized control trial. *Anesthesiology* 2015; **123**: 1033–41
24. Asai T. Emergency cricothyrotomy: toward a safer and more reliable rescue method in "cannot intubate, cannot oxygenate" situation. *Anesthesiology* 2015; **123**: 995–6
25. Kristensen MS, Teoh WH, Rudolph SS. Ultrasonographic identification of the cricothyroid membrane: best evidence, techniques, and clinical impact. *Br J Anaesth* 2016; **117**(Suppl. 1): i39–48
26. Sustic A, Miletic D, Protic A, Ivancic A, Cicvaric T. Can ultrasound be useful for predicting the size of a left double-lumen bronchial tube? Tracheal width as measured by ultrasonography versus computed tomography. *J Clin Anesth* 2008; **20**: 247–52
27. Lakhal K, Delplace X, Cottier JP, et al. The feasibility of ultrasound to assess subglottic diameter. *Anesth Analg* 2007; **104**: 611–4

Handling editor: T. Asai