



## Accuracy of identifying the cricothyroid membrane by anesthesia trainees and staff in a Canadian institution

## Exactitude du repérage de la membrane cricothyroïdienne par des stagiaires et des patrons en anesthésie dans un établissement canadien

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### Abstract

**Purpose** We sought to determine the rate of successful identification of the cricothyroid membrane by anesthesia residents and staff at a Canadian institution.

**Methods** In this prospective study, healthy adult volunteer subjects were positioned supine with their necks placed in neutral position. There were 12 subjects, half of whom were non-obese (body mass index < 30.0 kg·m<sup>2</sup>) and

half of whom were obese. There were equal numbers of male and female subjects in each of the obese and non-obese groups. Anesthesia staff and resident participants were allowed to palpate multiple subjects but with only one attempt per subject. For each subject, ultrasonography was used to identify the superior and inferior borders of the cricothyroid membrane, which were then marked with “invisible” ink that could be made visible with ultraviolet light. The midline was also marked with invisible ink. Identification of the cricothyroid membrane was considered correct if the mark was between the superior and inferior borders and within 0.5 cm of the midline.

**Results** Altogether, 61 participants palpated 12 subjects, resulting in 186 identifications. The success rates for the subgroups were as follows: non-obese men 72% (95% confidence interval [CI] 59 to 85%); obese men 39% (95% CI 26 to 54%); non-obese women 24% (95% CI 12 to 36%); obese women 35% (95% CI 21 to 49%).

**Conclusion** Success rates for correct identification of the cricothyroid membrane were poor in this Canadian institution.

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**Author contributions** Austin Lamb had roles in the study design, data collection, and data analysis and is the primary author of all drafts of the manuscript. Orlando Hung made substantial contributions to the conception and design of the study, data acquisition, analysis and interpretation of data, and drafting of the manuscript. Jinbin Zhang made significant contributions to data analysis and interpretation, as well manuscript writing. Bruce Flemming was actively involved in developing our method of ultrasonographic assessment for locating the cricothyroid membrane, performed real-time assessment of the neck using ultrasonography, and had input into manuscript writing. Tim Mullen participated significantly in the study design, collection of data, and revision of the manuscript. Mary Beth Bissell contributed to raw data extrapolation, and data manipulation for the graph designs. She was involved in manuscript editing. Iain Arseneau participated in data collection, most notably image capture, and contributed to the formatting and organization of data as well as the design of the scatter plots, and approved the draft manuscript.

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### Résumé

**Objectif** Nous avons cherché à déterminer le taux de réussite de l'identification de la membrane cricothyroïdienne par des résidents et des patrons en anesthésie dans un établissement canadien.

**Méthodes** Dans cette étude prospective, des adultes volontaires en bonne santé ont été placés en décubitus dorsal, avec le cou en position neutre. Il y a eu 12 sujets volontaires, la moitié d'entre eux n'étaient pas obèses (indice de masse corporelle < 30,0 kg·m<sup>2</sup>) et l'autre moitié l'était. Il y avait un nombre égal d'hommes et de femmes dans chaque groupe obèse et non obèse. Les patrons et les

*résidents d'anesthésie participants étaient autorisés à palper plusieurs sujets, mais ne pouvaient faire qu'un seul essai par sujet. Pour chaque sujet, une échographie a permis d'identifier les limites supérieure et inférieure de la membrane cricothyroïdienne qui ont alors été marquées avec de l'encre « invisible » qui ne pouvait apparaître qu'en lumière ultraviolette. La ligne médiane était également marquée avec de l'encre invisible. Le repérage de la membrane cricothyroïdienne était considéré comme réussi si la marque se trouvait entre ses limites supérieure et inférieure et à moins de 0,5 cm de la ligne médiane.*

**Résultats** Globalement, 61 participants ont palpé 12 sujets, aboutissant à 186 repérages. Les taux de succès pour les sous-groupes ont été les suivants: hommes non obèses 72 % (intervalle de confiance [IC] à 95 %: 59 % à 85 %); hommes obèses 39 % (IC à 95 %: 26 % à 54 %); femmes non obèses 24 % (IC à 95 %: 12 % à 36 %); femmes obèses 35 % (IC à 95 %: 21 % à 49 %).

**Conclusion** Les taux de succès d'un repérage correct de la membrane cricothyroïdienne ont été médiocres dans cet établissement canadien.

Clinicians face a “cannot intubate, cannot oxygenate” scenario when an unconscious patient cannot be oxygenated by bag-mask ventilation, a supraglottic airway device, or tracheal intubation. The American Society of Anesthesiologists Difficult Airway Algorithm recommends that a surgical airway be placed if spontaneous ventilation cannot be re-established in the anesthetized or unconscious patient in an emergent situation. The airway can be attained by tracheotomy or cricothyrotomy,<sup>1,2</sup> with the most popular emergency method employing the Seldinger percutaneous technique.<sup>3</sup> Thus, it is of paramount importance that anesthesia providers be able to identify the cricothyroid membrane accurately. Unfortunately, recent evidence suggests that anesthesiologists are challenged when attempting to locate the cricothyroid membrane, with ultimate success rates of 30% or less.<sup>4,5</sup> As these prior results are from New Zealand and Irish studies, our goal was to determine the success rate of palpating and identifying the cricothyroid membrane at a Canadian institution. We also hypothesized that obesity would decrease identification success.

## Methods

The Capital Health Research Ethics Board approved this prospective study in June 2012. Written informed consent was obtained from all recruited subjects and participants.

Those recruited to be palpated were termed “subjects.” Exclusion criteria for the subjects were age < 18 yr, known neck deformity, and previous neck surgery. In accordance with the National Institutes of Health, subjects were classified as “non-obese” if their body mass index was < 30.0 kg·m<sup>-2</sup> and “obese” if it was ≥ 30.0 kg·m<sup>-2</sup>.<sup>6</sup> Subjects were chosen such that there would be equal numbers of men and women as well as equal numbers of those who were non-obese and obese. The demographics of subjects – sex, age, weight, height, neck circumference – were recorded. The anesthesia staff and residents who attempted to identify the subjects’ cricothyroid membranes were the “participants.” Information collected from the participants included staff versus resident status, age, years since finishing their residency program, postgraduate year level (if currently a resident), whether the participant had performed his or her residency at our institution (if currently a staff member), history of performing a surgical airway, time since performing the most recent surgical airway training, cumulative time of surgical airway training, whether he or she had participated in an academic session on surgical airways within the last year, and average hours spent in the operating room per week. Each subject and participant was given an alphanumeric code, and each encounter between a subject and participant was given a random code number obtained from a random number generator (Excel<sup>®</sup>; Microsoft Corporation, Redmond, WA, USA). This process was used to provide anonymity of the identifications so an independent reviewer of the data at a later date would be blinded to the identities of the subjects and participants.

All studies were performed in the regional anesthesia “block room” with ultrasonography availability at the Halifax Infirmary in Halifax between June and August 2012. All of the participants were recruited from a list of residents and anesthesia staff scheduled to work at the Halifax Infirmary on the study days.

The study subjects were positioned supine on a stretcher with the neck placed in the neutral position and the forehead taped to the stretcher. This position was thought to reflect what might occur if a patient was subjected to in-line stabilization, such as after having suffered trauma with the cervical spine not yet cleared. Only one subject was available for identification at a time, and only one attempt at identification was allowed for an individual participant. Multiple participants could palpate each subject’s neck, but a participant was not allowed to palpate a given subject’s neck more than once. The participant was not informed of whether their identification was successful.

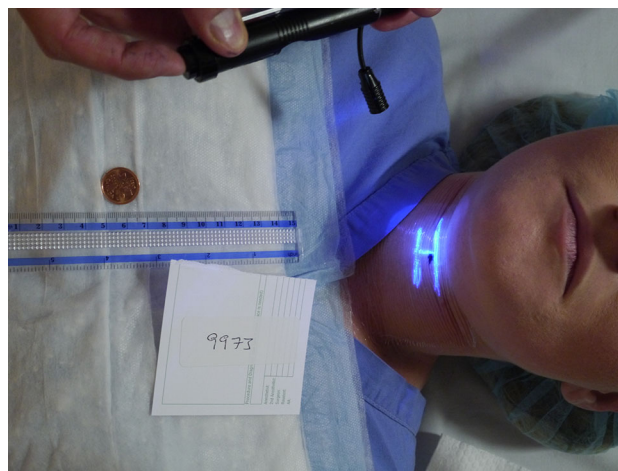
The superior and inferior borders of the cricothyroid membrane of each subject were demarcated using the method employed by Elliott *et al.* with minor variations.<sup>4</sup> A linear probe of the SonoSite MicroMaxx<sup>®</sup> (SonoSite Inc.,

Bothell, WA, USA) ultrasonography machine was used by a radiologist experienced in neck ultrasonography. A metal Arrow Guidewire (Arrow International, Inc., Reading, PA, USA) was placed in the transverse plane between the ultrasonography probe and the subject's skin at the superior and inferior borders of the cricothyroid membrane, thereby creating a drop-out shadow effect underneath the hyperechoic guidewire on the ultrasonography image. These borders were subsequently marked using an invisible-ink pen (Security Magic Invisible Ink Marker UV Spy Pen; China), the markings of which could be seen when exposed to ultraviolet light (Fig. 1). The markings on all subjects were covered by a 10 × 12 cm clear tape Tegaderm™ Film (3M Health Care, St. Paul, MN, USA).

Each participant was asked to use a black, fine-tipped, water-soluble white board marker (Quartet ReWritables Mini Dry-Erase Marker; ACCO Brands, Lake Zurich, IL, USA) to place a mark on the neck at the location that they thought most accurately represented the centre of the cricothyroid membrane. Once the participant had left the room, a photograph of the participant's mark on the subject's neck was taken for subsequent measurements. Each photograph revealed the invisible ink markings and the participant's mark, a ruler and penny for scale, and the random code number assigned to each subject–participant encounter (Fig. 1). After the photograph was obtained, the mark made by the participant was removed from the Tegaderm™ dressing so the next participant could make a mark without disrupting the original invisible ink marks under the Tegaderm™ Film.

An independent anesthesiologist who was not involved with the data collection performed all of the measurements on the photographs using digital calipers (Neiko Tools; Wenzhou, China). The photographic appearance, using the ruler in the photograph for scale, determined the success or failure of identifying the cricothyroid membrane. If the participant's mark was within both the superior and inferior borders of the cricothyroid membrane and within 0.5 cm of the midline, the participant's mark was deemed to be overlying the cricothyroid membrane, as was done in the Aslani *et al.* study<sup>5</sup> – thus, a successful identification. Otherwise, the mark was recorded as a failure, and the “direction of the miss” was recorded.

All attempts to identify the cricothyroid membrane by the participants were videotaped for off-line analysis. The majority of attempts were made from the right side of the subject, although occasionally the participant chose to palpate from the head of the bed or the left side. The “time to identification” for each attempt was defined as the point at which the participant first touched the subject's neck until he or she made their final mark. After each mark, the participant used a 10-cm horizontal visual analogue scale (VAS) to record the subjective difficulty of identifying the



**Fig. 1** Invisible ink markings are revealed using ultraviolet light

cricothyroid membrane. The scale ranged from the “easiest imaginable identification” (0) to an “impossible identification” (10).

The sample size for this experiment was calculated using the powerMediation package in R-3.0.3 software (R Core Team; Vienna, Austria). Using the success rates found by Aslani *et al.*,<sup>5</sup> a sample size analysis was conducted using a probability of successfully identifying the cricothyroid membrane in obese patients at 0% and in non-obese patients at 24% (with subjects in the neutral position). Obesity was to be controlled for during the experiment to ensure that 50% of the identifications were attempted on obese subjects. Our calculations indicated that a sample size of 56 examinations divided between the two palpated groups (non-obese and obese) would have the desired power of 0.8 and  $\alpha = 0.05$  (two-sided) for analysis using a logistic regression model. Data were analyzed using the statistical software R-3.0.3. Our sample size calculation did not account for within-subject and within-participant correlations.

Each subject was examined multiple times (by different participants), and each participant performed multiple examinations. We employed a mixed-effects logistic regression model to account for the within-subject and within-participant correlations. Obesity and sex were included in the model as fixed effects, and subjects and participants were included as random effects. Including random effects for subjects allows each subject to have his or her own “baseline” success rate. Similarly, by including random effects for participants, each participant has his or her own baseline successful identification rate. Model variables were tested for significance using the likelihood ratio test. Confidence intervals were calculated using the formula  $\hat{p} \pm z_{\alpha/2} \sqrt{\hat{p}(1-\hat{p})/n}$ , where  $\hat{p}$  represents the sampling proportion and  $z_{\alpha/2} = 1.96$  for a 95% confidence interval (CI).

## Results

The subjects' demographic characteristics are summarized in Table 1, and the participants' characteristics are in Table 2. There were 186 participant attempts to identify the cricothyroid membrane in 12 subjects. The overall success rate was 42% (79/186). In all, 85% (159/186) of the identifications were within the lateral borders of the cricothyroid membrane, and 48% (89/186) were within the superior and inferior borders.

The median (interquartile range [IQR]) time to identification was 21.8[14.6-32.4] sec, and the median [IQR] VAS score was 3.9 [1.8-6.6] cm. The time to identification and the VAS scores were correlated, with an  $R^2$  value of 0.51.

The success rate, difficulty of identification, and time to identification for each subject are provided in Table 3. The subject-based success rates ranged from 0 to 93%. The logistic regression identified a significant sex-by-obesity interaction ( $P = 0.046$ ). On average, a much lower success rate was seen for obese men than for non-obese men, whereas the success rates were low in both non-obese and obese women (Table 4). The success rates for the demographic subgroups were as follows: non-obese men 72% (95% CI: 59 to 85%); obese men 39% (95% CI: 26 to 54%); non-obese women 24% (95% CI: 12 to 36%); obese women 35% (95% CI: 21 to 49%).

Among the non-obese men, 85% (11/13) of unsuccessful identifications were in the superior vs inferior direction. Among the obese men, 86% (24/28) of unsuccessful

**Table 1** Summary of subject characteristics

Subject	Males					Females						
	Non-obese			Obese		Non-obese			Obese			
Age	37	21	58	22	50	37	26	27	24	37	56	43
BMI ( $\text{kg}\cdot\text{m}^{-2}$ )	26.0	22.2	26.8	31.7	38.1	33.5	23.1	22.6	21.8	31.6	30.1	38.3
Weight (kg)	82.8	69.6	76.2	96.5	99.3	125.9	66.5	60.7	59.4	81.3	75.8	91.4
Height (cm)	178.5	177.0	168.5	174.5	161.5	194.0	169.5	164.0	165.0	160.5	158.5	154.5
Neck circumference (cm)	39.4	35.6	37.3	40.9	42.9	49.4	33.1	30.3	33.0	38.1	38.3	33.7
Depth from skin to cricothyroid membrane (mm)	6.9	3.9	3.8	5.7	3.3	3.1	4.2	5.0	5.3	8.0	4.7	9.0
Cricothyroid membrane height (cm)	12.6	11.2	8.8	10.0	5.6	5.5	10.2	9.0	7.2	8.4	5.5	9.1

BMI = body mass index

**Table 2** Summary of participant characteristics

Participant	Staff ( $n = 41$ )	Resident ( $n = 20$ )	Total ( $n = 61$ )
Age	47.0 (40.0-53.5)	29.0 (27.0-34.3)	41.0 (31.5-49.0)
Years since finishing residency	13.0 (7.0-19.0)	N/A	N/A
Postgraduate year level	N/A	3.0 (2.0-5.0)	N/A
Percent who have performed surgical airway in real clinical scenario	27%	10%	21%
Percent who have done surgical airway training on mannequins/cadavers	7%	25%	13%
Cumulative time spent in surgical airway training (hr), staff $n = 38$ , resident $n = 15$ , total $n = 53$	1.5 (1.0-3.0)	1.0 (0.1-2.0)	1.0 (0.5-2.8)
Time since surgical airway training (months)	60.0 (36.0-108.0)	8.0 (6.0-24.0)	48.0 (12.0-84.0)
Percent who have been in academic session on surgical airways within last year	61%	50%	57%
Percent who prefer percutaneous to open technique	78%	75%	77%
Average time in operating room per week (hr)	45.0 (33.5-50.0)	45.0 (36.3-58.8)	45.0 (35.0-50.0)

Data represent median (interquartile range)

**Table 3** Identification success rate by individual subject

Subject	Successful Identifications/ Total Examinations	Success Rate	VAS (cm)	TTI (sec)	Subject Subgroup
1	10/13	77%	1.3 (0.9-2.2)	17.5 (12.4-44.0)	Non-obese male
2	13/14	93%	0.4 (0.2-0.9)	12.0 (9.7-18.8)	Non-obese male
3	10/19	53%	2.1 (1.6-3.6)	16.1 (13.7-23.1)	Non-obese male
4	11/16	69%	3.4 (2.6-4.4)	23.9 (13.9-31.6)	Obese male
5	2/17	12%	6.8 (4.9-7.6)	22.8 (16.9-36.3)	Obese male
6	5/13	38%	5.4 (3.9-6.3)	18.6 (13.6-32.1)	Obese male
7	5/19	26%	4.9 (2.1-6.8)	26.8 (22.0-35.2)	Non-obese female
8	6/17	35%	2.5 (1.3-4.8)	16.4 (15.2-34.7)	Non-obese female
9	0/9	0%	1.5 (0.3-2.9)	14.8 (12.2-25.7)	Non-obese female
10	4/18	22%	5.2 (3.2-6.4)	26.6 (14.5-44.3)	Obese female
11	10/17	59%	7.9 (6.6-8.6)	28.7 (21.6-48.7)	Obese female
12	3/14	21%	5.5 (4.3-7.0)	21.9 (15.3-27.5)	Obese female

Data represent median (interquartile range); TTI = time to identification; VAS = visual analogue scale

**Table 4** Odds ratio of identification by subject demographic group

Subject	Men		Women		Odds ratio (95% CI) for male sex within strata of obesity
	N	Odds ratio (95% CI)	N	Odds ratio (95% CI)	
Non-Obese	33/46	12.4 (2.3 to 65.8); $P = 0.003$	11/45	1.0 (Reference)	12.4 (2.3 to 65.8); $P = 0.003$
Obese	18/46	2.4 (0.3 to 22.1); $P = 0.04$	17/49	1.90 (0.4 to 9.0); $P = 0.42$	1.2 (0.08 to 20.3); $P = 1.0$
Odds Ratio (95% CI) for Obesity within strata of sex		0.2 (0.01 to 2.9); $P = 1.0$		1.90 (0.4 to 9.0); $P = 0.42$	

Measure of effect modification on additive scale: RERI (95% confidence interval [CI]) =  $-10.95$  ( $-14.07$  to  $-7.82$ );  $P < 0.05$  ( $4.0 \times 10^{-7}$ )

Measure of effect modification on multiplicative scale: ratio of odds ratios (ORs) (95% CI) =  $0.10$  ( $0.01$  to  $0.94$ );  $P = 0.044$

identifications were in the inferior vs superior direction. Among non-obese women, 65% (22/34) of the unsuccessful identifications were in the superior vs inferior direction. Among obese women, 88% (28/32) of unsuccessful identifications were in the superior vs inferior direction.

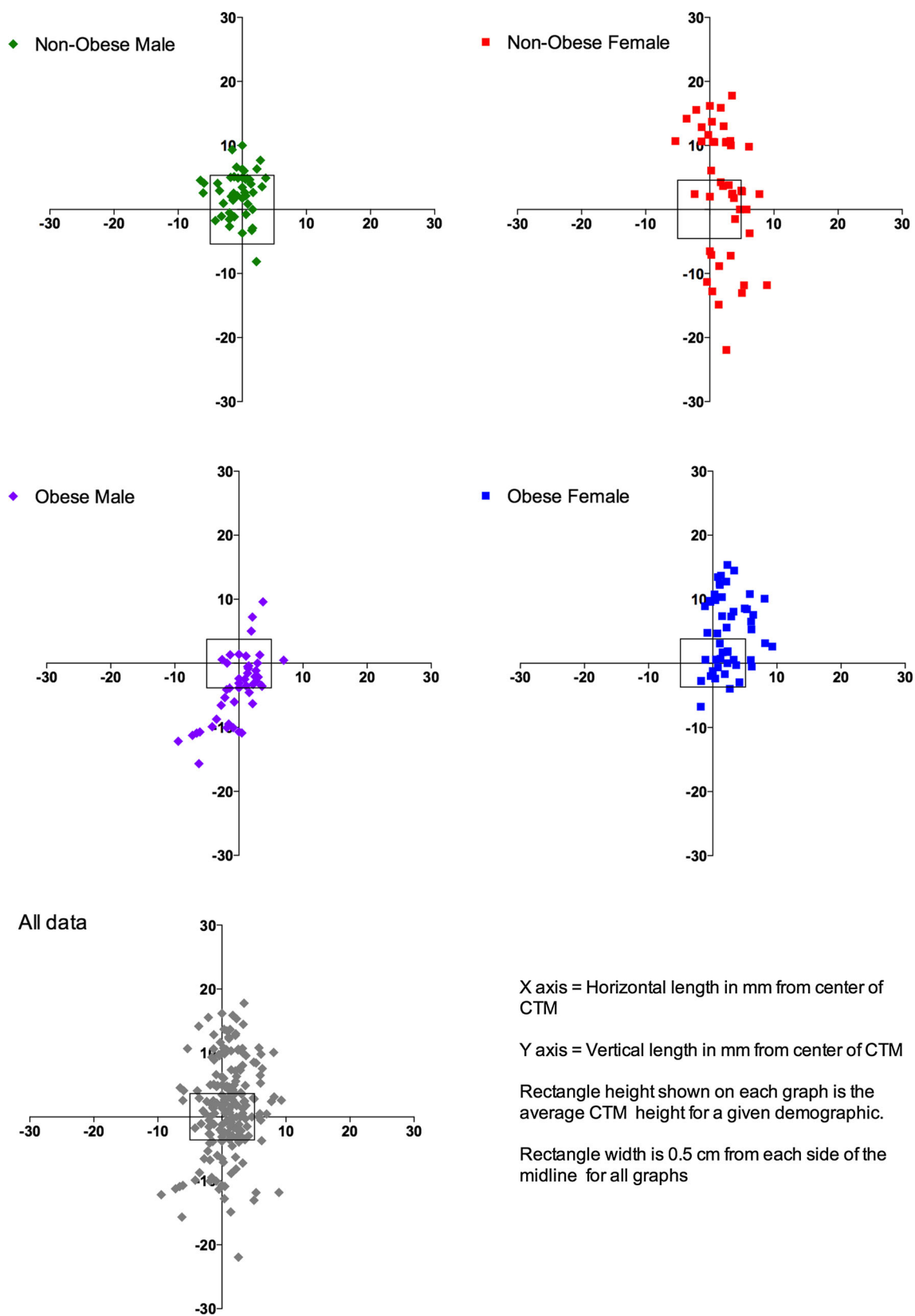
Staff anesthesiologists performed 109 of the 186 identifications, and residents performed the remaining 77. The staff anesthesiologists had a 40% (44/109) rate of successful identifications, as did 45% (35/77) of the residents. Scatter plots in Fig. 2 show the overall marked cricothyroid locations: the overall marks and by subgroup.

## Discussion

This study found an overall success rate of 42% for cricothyroid membrane identification by anesthesia staff and residents at our institution. This is a slightly higher success rate than the 30% success rate reported by Elliott

*et al.* However, interpretation of this difference is complicated by differences in the composition of the subjects in the two studies.<sup>4</sup> Aslani *et al.*, studying women placed in neutral and extended neck positions, found success rates of 24.4% and 29.3%, respectively, in non-obese women, whereas in obese women the success rates were 0% and 6.7%, respectively.<sup>5</sup>

Variations in sampling among our study, the Elliott *et al.* study,<sup>4</sup> and the Aslani *et al.* study<sup>5</sup> could explain the differing results. All of the participants palpated the same set of subjects in the Elliott *et al.* study. Four of their six subjects were obese, whereas six of twelve of our subjects were obese. As with our study, however, there was an equal proportion of male and female subjects (50%). Some participants in the Aslani *et al.* study palpated more than one subject. Roughly three quarters of the identifications in the Aslani *et al.* study were in non-obese subjects, whereas we included an approximately equal number of identifications in non-obese and obese subjects, even when taking sex into account.



**Fig. 2** Placement of neck marks made by participants on subjects, by demographic variable. Individual participant marks on individual subjects were used to determine success or failure of identification and subsequent data analysis

In our study, both non-obese men (odds ratio [OR] 12.4, 95% CI: 2.3 to 65.8;  $P = 0.003$ ) and obese men (OR 2.4, 95% CI: 0.3 to 22.1;  $P = 0.04$ ) had significantly higher rates of identification relative to the rate for non-obese women. Despite non-obese men providing the highest success rate – 72% (95% CI: 59 to 85%) – this figure is still suboptimal when considering that the goal is 100% and the consequences of misidentification could be fatal. Obesity did not significantly affect success rates among the men (OR 0.2, 95% CI: 0.01 to 2.9;  $P = 1.0$ ). Similarly, the cricothyroid membrane of obese men was not identified at a higher rate than in obese women (OR 1.2, 95% CI: 0.08 to 20.3;  $P = 1.0$ ).

The cricothyroid membrane was successfully identified at a lower rate in non-obese women (24%, 95% CI: 12 to 36%) than in obese women (35%, 95% CI: 21 to 49%). The OR for successful identification in obese women relative to non-obese women did not reach significance (OR 1.9, 95% CI: 0.4 to 9.0;  $P = 0.42$ ).

In our study, participants more often missed identifying the cricothyroid membrane in the superior direction, particularly in obese women. This is perhaps due to mistaking the thyrohyoid membrane for the cricothyroid membrane when the landmarks were not distinct.<sup>7</sup> In non-obese women, however, misses occurred in the inferior direction as well, possibly because tracheal cartilages are more easily palpated in non-obese women than in obese women. In obese men, the direction of the miss was more likely to be in the inferior direction, possibly because of their more easily palpated thyroid prominence and tracheal cartilages. Elliott *et al.* also reported that a greater proportion missed in the superior direction but did not explore the direction of the misses as they related to the subjects' demographics.<sup>4</sup>

The Fourth National Audit Project (NAP4) of the Royal College of Anaesthetists and the Difficult Airway Society reported that there is a high failure rate when performing emergency cannula cricothyrotomy. In the NAP4, anesthesiologists used a percutaneous technique “almost exclusively”, and their success rate was 36%.<sup>8</sup> Failures required rescue by an open technique in the vast majority of cases, and all open techniques were able to gain access to the airway.<sup>1</sup> The NAP4 did not examine the causes of failure. Although they are likely multifactorial, difficulty locating the cricothyroid membrane could be a contributor. NAP4 mentioned misplacement and “cephalad placement of the device” as contributors to failure of cannula cricothyrotomy in the NAP4.<sup>8,9</sup> The degree to which missed identification of the cricothyroid membrane contributes to failure of an emergency cannula cricothyrotomy, however, remains to be determined.

The recently updated Canadian Airway Focus Group recommendations take into account the high failure rates of

percutaneous techniques and the evidence that anesthesiologists have a poor rate of identifying the cricothyroid membrane.<sup>10</sup> Their recommendations suggest that before a percutaneous technique is attempted in a patient in whom landmarks are not easily identifiable, a 3-cm vertical midline skin incision may be helpful for identifying the cricothyroid membrane underneath it. The recommendations also suggest a very low threshold for converting to an open technique should any difficulty be encountered with the percutaneous technique.<sup>10</sup> Unfortunately, although there is evidence to suggest a higher failure rate with percutaneous techniques, a recent survey of Canadian anesthesiologists demonstrated that only 18% of respondents would be comfortable performing an open technique.<sup>3</sup> Our data collection indicated that 77% preferred a percutaneous technique as the first option for cricothyrotomy, suggesting that most anesthesia personnel at our institution would not choose the open technique as their first option.

In this study, past simulation experience of the participants did not result in a difference in success. Simulation often focuses on the procedure itself rather than locating the cricothyroid membrane, which is assumed by many practitioners to be straightforward. Kuduvalli *et al.* reported that the skill needed to perform a cricothyrotomy fades at six months or less.<sup>11</sup> In a separate study, however, Boet *et al.* found that the skill can be retained for at least twelve months.<sup>12</sup> These studies were done on mannequins and did not focus on identifying the cricothyroid membrane. The average time that had elapsed since any surgical airway training in our study was more than one year for residents and nearly seven years for staff anesthesiologists.

Although we employed ultrasonography in this study to delineate the superior and inferior borders of the cricothyroid membrane, we caution using it in an emergency “cannot intubate, cannot oxygenate” situation. The use of ultrasonography to locate the cricothyroid membrane requires practice and technical expertise to acquire the correct image and then interpret it properly. Ultrasonography also cannot be used in scenarios where there is subcutaneous air, as anatomical structures distal to the air are not visualized easily using ultrasonography.<sup>13-16</sup> Additionally, an ultrasonography machine is not always immediately available in an emergency scenario, and the “boot-up” time may be unacceptably slow. Other steps required for the use of ultrasonography (e.g., gel application, probe selection, image configuration) further delay the cricothyrotomy. In a study involving emergency physicians and 50 patients, localization of the cricothyroid membrane using ultrasonography took a mean of 24.32 sec (SD = 20.18 sec, 95% CI = 18.59 to 30.05 sec).<sup>17</sup> A recent small French study involving twelve residents

found that identification of the cricothyroid membrane was easier to locate with ultrasonography than with direct palpation in a comparable amount of time.<sup>18</sup> The authors of both of these studies did not mention whether they took into account the time required for preparation of the ultrasonography device and other necessary equipment. Therefore, the role of ultrasonography-guided emergency cricothyrotomy remains to be determined.

In the rare scenario where cricothyrotomy is part of the backup airway management plan and there is time to locate the cricothyroid membrane ahead of time, ultrasonography may have a role in locating its borders. Additionally, when the locations of the trachea and cricothyroid membrane are not obviously due to neck pathology, ultrasonography may help locate the relevant anatomic structures.<sup>19-21</sup>

This study has several limitations. Because of the skin folds in obese subjects, it was more difficult to delineate the borders accurately and subsequently to apply the invisible ink. Our data demonstrated that the median [IQR] cricothyroid membrane height was 9.0 [6.5-9.6] mm, which is less than the average cricothyroid membrane height observed by others. One cadaveric study reported it to be 10.4 mm.<sup>22</sup> The discrepancy in cricothyroid membrane height may have been due to the ultrasound probe used to visualize the borders. Also, cadaveric measurements may be different from those of live subjects because of postmortem tissue changes and cadaver preparation.

Identification may have been more challenging because attempts were done with the neck of the subject placed in neutral position and without extension. On occasion, participants moved the overlying skin when they made their mark on the subject's neck, so the mark did not indicate the exact site the participant thought was the centre of the cricothyroid membrane.

In summary, our data confirmed the findings of other studies that anesthesiologists have a low success rate for identifying the cricothyroid membrane. The highest rate for identifying the cricothyroid membrane was in non-obese men. Recently, the Canadian Airway Focus Group recommended that an incision over the cricothyroid membrane could improve the success rate for Seldinger cricothyrotomy. Our study provides support for a 3-cm vertical skin incision over the presumed location of the cricothyroid membrane as it may help with identification during cricothyrotomy if the clinician chooses a percutaneous technique. Future studies are needed to determine the best technique for identifying the cricothyroid membrane.

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## Appendix

See Appendix for Table 5, which delineates the number of palpations performed by participants.

**Table 5** Frequency of palpations

Number of Palpations	Number of Participants
1	16
2	13
3	9
4	11
5	4
6	4
7	3
8	1

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