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REPORTS OF ORIGINAL INVESTIGATIONS

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

Comparaison des taux de réussite des anesthésistes et des chirurgiens de trauma dans l'utilisation de la palpation pour identifier la membrane cricothyroïdienne chez des patientes: une étude observationnelle prospective

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Abstract
Purpose *The primary aim of this study was to compare the success rates of anesthesia providers vs trauma surgeons in their use of palpation to identify the cricothyroid membrane (CTM). The secondary aim was to explore whether prior training and experience performing surgical airways affected the success rates for identifying the CTM.*
Methods *Four female adults participated in this prospective observational study. The participants had varying measurements of neck anatomy that were known or theorized to affect the accuracy of identifying the CTM location. For test purposes, the subjects were positioned with optimal neck extension via placement of a shoulder roll. Anesthesia providers (n = 57) and surgeons (n = 14) of various training levels and clinical experience marked the presumed CTM location on each subject. These palpation markings were then referenced against the ultrasound-confirmed CTM location, and the success rates for identifying the CTM were compared between groups.*
Results *The overall success rate using palpation to identify the CTM was ≤ 50%, and there were no differences in success rates between the anesthesia providers and trauma surgeons (16% vs 26%, respectively; absolute difference, −10%; 95% confidence interval, −23 to 3; P = 0.15). Furthermore, there were no significant differences in the success rates for identifying the CTM based on either clinical experience or emergency surgical airway experience.*
Conclusion *The success rates for identifying the CTM using palpation were low and not significantly different for anesthesia providers and surgeons, collectively, as well as for the various levels of training. Anesthesiologists' ability to mark the CTM location correctly did not improve with years of experience.*

This article is accompanied by an editorial. Please see Can J Anesth 2016; 63: this issue.

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Résumé

Objectif *L'objectif principal de cette étude était de comparer les taux de réussite des anesthésistes et des chirurgiens de trauma dans leur utilisation de la palpation pour identifier la membrane cricothyroïdienne (MCT). L'objectif secondaire était d'évaluer si une formation et de l'expérience antérieures en matière de voies aériennes chirurgicales affectait les taux de réussite de l'identification de la MCT.*

Méthode *Quatre femmes adultes ont participé à cette étude observationnelle prospective. Les participantes présentaient diverses anatomies du cou qui, selon nos connaissances ou nos présomptions, pourraient affecter la détermination précise de l'emplacement de la MCT. Aux fins de notre expérience, les patientes ont été positionnées avec une extension optimale du cou en plaçant un rouleau sous leurs épaules. Des anesthésistes (n = 57) et des chirurgiens (n = 14) possédant différents niveaux de formation et d'expérience clinique ont marqué l'emplacement présumé de la MCT sur chaque patiente. Ces marques de palpation ont par la suite été comparées à l'emplacement de la MCT confirmé par échoguidage, et les taux de réussite de l'identification de la MCT ont été comparés entre les groupes.*

Résultats *Le taux de réussite global de la palpation pour identifier la MCT était ≤ 50%; aucune différence n'a été observée dans les taux de réussite entre anesthésistes et chirurgiens de trauma (16% vs 26%, respectivement; différence absolue, −10%; intervalle de confiance 95%, −23 à 3; P = 0,15). De plus, aucune différence significative en matière de taux de réussite de l'identification de la MCT n'a été observée en fonction de l'expérience clinique ou de l'expérience avec des voies aériennes chirurgicales en urgence.*

Conclusion *Les taux de réussite d'identification de la MCT à l'aide de la palpation étaient bas et ne montraient pas de différence significative entre les anesthésistes et les chirurgiens, pris ensemble, ainsi qu'entre les différents niveaux de formation. La capacité des anesthésiologistes à marquer l'emplacement de la MCT correctement ne s'est pas améliorée avec des années d'expérience.*

Initial airway management can ultimately progress to a "cannot intubate, cannot oxygenate" scenario that requires the creation of an emergency surgical airway. This situation can arise independent of location (pre- or in-hospital setting),[1-3] clinical expertise (medical technician, nurse, or physician),[4,5] or specialty (emergency medicine, anesthesiology, critical care medicine, or surgery).[6-8] The most recent American Society of Anesthesiologists' (ASA) "Practice Guidelines for Management of the Difficult Airway" designate surgical or percutaneous airway, jet ventilation, or retrograde intubation as invasive airway access procedures to secure the airway in both non-emergency and emergency situations.[9] Each of these techniques is usually performed at the cricothyroid membrane (CTM). Furthermore, if creation of an emergency surgical airway is necessary, anesthesiologists are more likely to perform a percutaneous cricothyrotomy than either a surgical cricothyrotomy or a tracheostomy.[10,11] Training and anatomical factors may explain this preference. The CTM is more superficial in the neck, potentially less vascular, and not obscured by the isthmus of the thyroid gland when compared with the trachea[12] (Fig. 1B). Additionally, the posterior wall of the cricoid cartilage can be protective to inadvertent puncture.

When an anesthesia provider attempts a percutaneous or surgical (i.e., open) cricothyrotomy, it may not be performed correctly, as these practitioners are not as adept at CTM identification or in the performance of these techniques when compared with surgeons.[7,13-16] Results of the "Fourth National Audit Project" revealed that anesthesiologists failed to perform a successful percutaneous emergency surgical airway 64% of the time when attempted in the *cannot intubate, cannot oxygenate* setting.[7] Conversely, this audit revealed that all three open cricothyrotomies and 29 tracheostomies were performed successfully (presumably by surgeons) as first choice options for emergency surgical airways.[7]

The first step in the performance of an emergency cricothyrotomy is accurate identification of the CTM, which is often not an easy task in both non-emergency and emergency situations.[5,13,15-17] Predictors of difficult cricothyrotomy include difficulty identifying the location of the CTM (Fig. 1) and difficulty accessing the trachea through the anterior neck.[17,18] In 2003, the ASA "Practice Guidelines for Management of the Difficult Airway" recommended that anesthesiologists routinely assess patients for possible difficult tracheostomy.[19] This recommendation was modified in the latest guidelines to include assessment for possible difficult surgical airway access.[9]

An initial step toward improved outcomes when performing an emergency cricothyrotomy should include formulating a reliable clinically validated technique for identifying the CTM. The primary aim of this study was to compare the success rates of anesthesia providers *vs* trauma surgeons in their use of palpation to identify the CTM. We hypothesized that trauma surgeons would be significantly better than anesthesia providers at identifying the CTM location. The secondary aim of this study was to explore whether prior training and experience in performing surgical airways would affect the success rates of CTM identification. Previous related studies lack trauma surgeons as participants.[13,15,16]

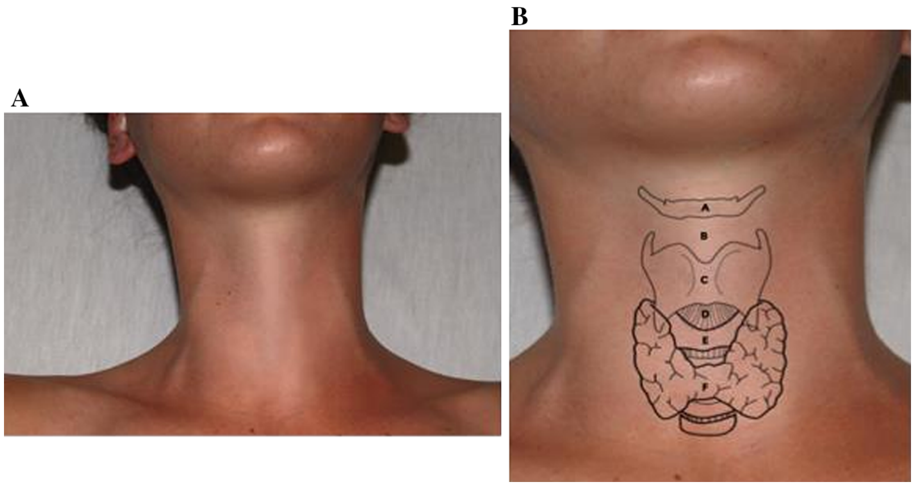

Fig. 1 A. Photograph of the anterior neck of a thin female. Notice that the thyroid cartilage/CTM are not visually identifiable. B. Photograph of the same female with underlying anatomy superimposed. A—hyoid bone, B—thyrohyoid membrane, C—thyroid cartilage, D—CTM, E—cricoid cartilage, F—surgical tracheostomy site (between second and third tracheal rings). Used with permission from *Hagberg CA*. Airway blocks. *In*: Chelly JE (Ed). Peripheral Nerve Blocks: A Color Atlas, 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 2009: 181. CTM = cricothyroid membrane

Methods

This study was conducted following approval from the Institutional Review Board of McGovern Medical School (HSC-MS-14-0530; August 2014). The test subjects and study participants provided written informed consent. Four healthy female adults were enrolled as test subjects. Characteristics and anatomic measurements of the subjects are listed in Table 1. Female subjects were chosen because identification of the CTM can be more difficult in females than in males.[13,15] The subjects were chosen based on anatomic measurements known or hypothesized to affect the accuracy of identifying the CTM location, including body mass index,[13,15,16] neck circumference,[13,15,16] thyromental distance (TMD—i.e., the distance from the mentum to the thyroid notch),[13] sternomental distance (SMD—i.e., the distance from the suprasternal notch to the mentum with the head fully extended and the mouth closed),[13] and pre-tracheal soft tissue.[15,16] Characteristics and anatomic measurements of the subjects were as follows: Subject 1, non-obese female with a small neck circumference; Subject 2, morbidly obese female with a large neck circumference and significant pre-tracheal subcutaneous tissue; Subject 3, tall female with a small neck circumference; and Subject 4, non-obese female with the lowest TMD/SMD ratio of the four subjects. Subjects were positioned in a standardized fashion with the neck optimally extended (as the height of the CTM increases upon neck extension,[20] exposing a larger working area to perform a cricothyrotomy.

Table 2 represents participant characteristics of the anesthesia providers and surgeons. The recruited convenience sample size consisted of 71 participants, including 57 anesthesia providers and 14 surgeons. The study participants were classified by training and experience: Level 1, anesthesiology assistant (AA) students (n = 9); Level 2, AAs (n = 7); Level 3, clinical anesthesia (CA) residents (n = 23—i.e., 11 first year, six second year, and six third year) and postgraduate year (PGY) 1-5 surgery residents (n = 6); Level 4, faculty anesthesiologists with $<$ five years' experience (n = 11) and PGY 6-7 surgery residents (n = 3); and Level 5, faculty anesthesiologists with five years' experience (n = 7) and surgeons with five years' experience (n = 5). For comparison purposes, "experienced" was defined as five or more years of post-training clinical experience.

Standard training in invasive airway access for AA students, AAs, and anesthesiology residents consists of didactic components and simulation. Furthermore, our first and second year CA residents perform cricothyrotomies on exposed pig tracheas in a laboratory setting. No additional training was provided prior to or in anticipation of the study, and participants were not given the opportunity to prepare for the study. The study was conducted over a two-day period, with anesthesia providers participating one afternoon and surgeons participating the following morning.

Prior to studying the subjects, the following data were collected from the participants: level of training/years of experience; hand dominance; subjective confidence level for accurately identifying CTM location—indicated on a 10-cm horizontal visual analogue scale (VAS) from 0 (easiest) to 10 (most difficult); subjective confidence level for creating a surgical airway on a 10-cm VAS; and experience creating a surgical airway (non-emergency and emergency).

Table 1 Subject characteristics and anatomic measurements

	Subject 1	Subject 2	Subject 3	Subject 4
Age (yr)	47	38	25	28
Weight (kg)	72	123	88	44
Height (cm)	162	164	180	152
Neck circumference (cm)	37.2	44.5	37.6	29.5
Body mass index ($kg \cdot m^{-2}$)	27.4	45.7	27.2	19.0
TMD (cm)	6.8	6.0	7.0	4.2
SMD (cm)	12.3	12.7	18.0	11.8
TMD/SMD	0.55	0.47	0.39	0.36
CTM height (mm)	9	8	8	7
Depth from skin to CTM (mm)	5.0	11.0	4.5	4.0

CTM = cricothyroid membrane; TMD = thyromental distance; SMD = sternomental distance

Table 2 Characteristics of anesthesia providers and surgeons

Variables	Anesthesiology (*n* = 57)	Surgery (*n* = 14)	*P* value
Training Level, *n* (%)			
Level 1 (AA student)	9 (16)	0 (0)	NR
Level 2 (AA)	7 (12)	0 (0)	
Level 3 (CA 1-3, PGY 1-5)	23 (40)	6 (43)	
Level 4 (Faculty < 5, PGY 6-7)	11 (19)	3 (21)	
Level 5 (Faculty 5)	7 (12)	5 (36)	
Dominant Hand, *n* (%)	*n* = 56		
Left	8 (14)	3 (21)	0.68*
Right	48 (86)	11 (79)	
Number of surgical airways created, *n* (%)			
0	50 (88)	3 (21)	< 0.001*
> 0	7 (12)	11 (79)	
Self-rated confidence, VAS	5 [4-8]	3 [1-5]	0.03
Self-rated ability, VAS	5 [3-8]	2 [1-6]	0.03
Subject 1 VAS	3 [2-5]	3 [1-5]	0.39
Subject 1 Time (seconds)	8 [6-13]	9 [7-13]	0.59
Subject 2 VAS	6 [4-7]	5 [4-8]	0.81
Subject 2 Time (seconds)	11 [8-17]	9 [6-16]	0.32
Subject 3 VAS	5 [3-6]	6 [3-7]	0.39
Subject 3 Time (seconds)	10 [7-14]	9 [7-15]	0.70
Subject 4 VAS	2 [1-4]	2 [0-3]	0.25
Subject 4 Time (seconds)	7 [5-9]	5 [5-10]	0.31

Values are expressed as mean [interquartile range] unless otherwise indicated. *Denotes *P* value obtained by Fisher's exact test; other *P* values obtained by Wilcoxon rank-sum test. AA = anesthesiology assistant; CA = clinical anesthesia year; NR = not reported due to 0 cells; PGY = postgraduate year; VAS = visual analogue scale

All subjects were positioned in neck extension via a shoulder roll. A faculty otolaryngologist experienced in head and neck ultrasonography took the measurements of neck anatomy using the medium to high-frequency (4-13 MHz) linear transducer of a LOGIQ™ *e* ultrasound system (GE Healthcare, Wauwatosa, WI, USA). The ultrasonographer marked the superior and inferior borders and the sagittal midline of the CTM with a fine-point invisible ink marker that appeared pink under ultraviolet light.[16] A 10 cm x 12 cm waterproof transparent dressing (Tegaderm™, 3M Health Care, St. Paul, MN, USA) was placed over the markings.

Participants were provided stickers that included their unique identifier, and test subjects were numbered 1 to 4. Each participant rotated in a clockwise manner through the four individual test subject stations. Participants were placed at the subject's right side and were then requested to mark the middle of the CTM as quickly as possible using a fine-point yellow erasable invisible ink marker. Once the participant was confirmed ready, the timer was started and the participant was instructed to begin. Participants gently palpated the subject's neck, marked the presumed CTM location, and rated the difficulty of CTM identification on a 10-cm VAS. Participants were subsequently escorted out of the testing area. The sticker corresponding to that participant and subject was placed along the subject's anterior neck. The area was then illuminated with ultraviolet light, and a digital photo was taken perpendicular to the anterior neck. The markings on the transparent dressing were wiped off and the next participant was escorted into the room. The process was repeated with the majority of study participants rotating through all four stations.

Research assistants performed all measurements on the photographs using digital calipers (Adobe® Photoshop, Adobe Systems Incorporated, USA). First, the height of the CTM in the sagittal midline was measured in each photograph. The CTM height, as previously determined by ultrasound, served as a reference scale for each subject. The subject-specific reference height was divided by the CTM height in each photograph to generate a correction factor, adjusting for variations in focal distance between the camera and anterior neck. Second, the distance from the yellow invisible ink mark to the precise middle of the CTM was measured and multiplied by the correction factor for that photograph. This is represented by the following equation:

$$\text{Corrected distance from CTM middle} = \frac{\text{Reference CTM height}}{\text{Photograph CTM height}} \times \text{Measured distance from CTM middle}$$

Finally, the angle (0 - 360°) of each participant's yellow invisible ink mark was determined using Adobe® Photoshop. This process allowed x- and y-values for each participant's attempts to be calculated using the following trigonometric equations:

x-value = Corrected distance from CTM × [Cos (Angle/180 × 3.14)]

y-value = Corrected distance from CTM × [Sin (Angle/180 × 3.14)]

These x- and y-values were subsequently used to calculate the mean dispersion of all participants' attempts (Figs 2, 3, 4, 5). A participant mark within the subject-specific superior and inferior borders of the CTM and within 0.5 cm of the longitudinal midline[13,15] was considered successful. The criteria for success laterally was based on the greatest measured width (10.5 mm) of the trapezoidal CTM in females in a prior study.[12] Any mark outside of these borders was considered a failure.

Statistical analysis

Our primary objective was to compare the success rates of anesthesia providers *vs* trauma surgeons at our institution in their use of palpation to identify the CTM. Based on an estimated success rate for anesthesia providers of 30%,[13,15,16] this convenience sample of 57 anesthesia providers and 14 surgeons allowed the detection of > 52% absolute difference in the proportion of successful identification between anesthesia providers and surgeons, with 80% power at a 0.0125 level of significance after justification for multiple comparisons.

Participant characteristics were summarized and compared between anesthesia providers and surgeons. Categorical data were analyzed using the Fisher's exact test, and continuous data were analyzed using the Wilcoxon rank-sum test due to skewed data. Separate analysis was conducted for each subject using the Fisher's exact test to compare the success rates of CTM identification between participant groups. The Bonferroni correction was used to counteract the problem of multiple comparisons and to maintain the family-wise error rate when comparing success rates of both participant groups for a given subject. For analysis of an individual test subject with limited sample size, the exact method was used to calculate confidence intervals (CIs). For pooled data and large sample size, the standard Wald asymptotic method was used to calculate CIs. *Post hoc* multivariable logistic regression models were applied to evaluate the effect of prior training and surgical airway experience on CTM identification. *Post hoc* subgroup analyses were conducted to compare the success rates of CTM identification within different subgroups. All analyses were conducted using SAS® 9.3 (SAS Institute Inc., Cary, NC, USA).

Results

The 71 volunteer participants performed a total of 272 CTM examinations. Sixty-one (86%) of the 71 participants completed all four test subject stations as there were unanticipated clinical duties requiring some participants to leave the study prior to completing all four stations. No significant differences existed in the data analysis of complete cases compared with total cases (complete and

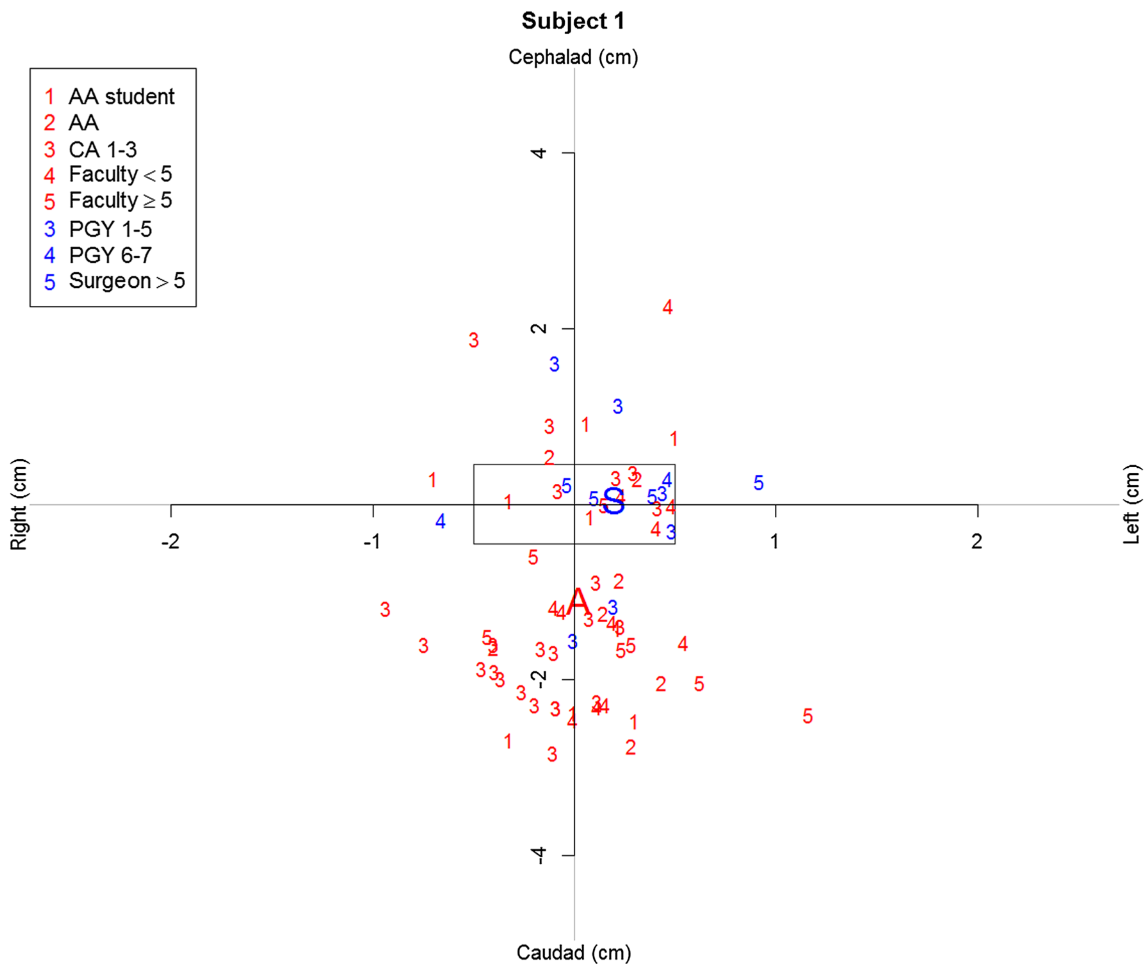

Fig. 2 Scatterplot of participant markings for Subject 1. Numbers represent specific training levels for participant groups. Red denotes anesthesia providers and blue denotes surgeons. For all subjects, success is defined as an absolute x-value 0.5 (within 5 mm of the sagittal midline),[13,15] with an absolute y-value defined by the ultrasonically measured CTM height/2. Success is defined as an absolute y-value 0.45. The letters "A" and "S" in each scatterplot denote the mean x- and y-values, respectively, for anesthesia providers and surgeons. CTM = cricothyroid membrane

available). Hand dominance was similar between anesthesia providers and surgeons (P = 0.68) (Table 2). Surgeons expressed greater confidence than anesthesia providers in their ability to be successful in identifying the CTM and performing a surgical airway (P = 0.03) (Table 2). Only seven (12%) of the 57 anesthesia providers compared with 11 (79%) of the 14 surgeons had previously performed surgical airways ($P < 0.001$) (Table 2).

Table 3 lists the success rates of anesthesia providers and surgeons in identifying the CTM with 95% CIs for each of the four subjects. Both participant groups had relatively low (≤ 50%) and not significantly different rates of success in identifying the CTM for all four subjects (16%, anesthesia provider *vs* 26%, surgeon; absolute difference, −9.8%; 95% CI, −22.9 to 3.3; P = 0.15) (Table 3). Separate multivariable logistic regression models did not show a significant difference in the success rate of CTM identification for all subjects based on either clinical experience (training level) or surgical airway experience for both participant groups (Tables 4 and 5). *Post hoc* subgroup analyses for training levels 3, 4, and 5 for both participant groups are presented in Table 4.

The perceived difficulty and time taken to mark the presumptive CTM location for Subjects 1 through 4 were not significantly different between anesthesia providers and surgeons (Table 2). The longest period of time taken among all four subjects was 46 sec for Subject 2 (morbidly obese female with a large neck circumference and significant pre-tracheal subcutaneous tissue). Subject 4 (non-obese female with a small neck circumference) was subjectively considered the easiest to identify the CTM location and required the least amount of time by both groups (Table 2).

Scatterplots of participants' marks for each subject are depicted in Figs 2-5. Mean values for Subject 2 show a leftward lateralization from the midline by both anesthesia

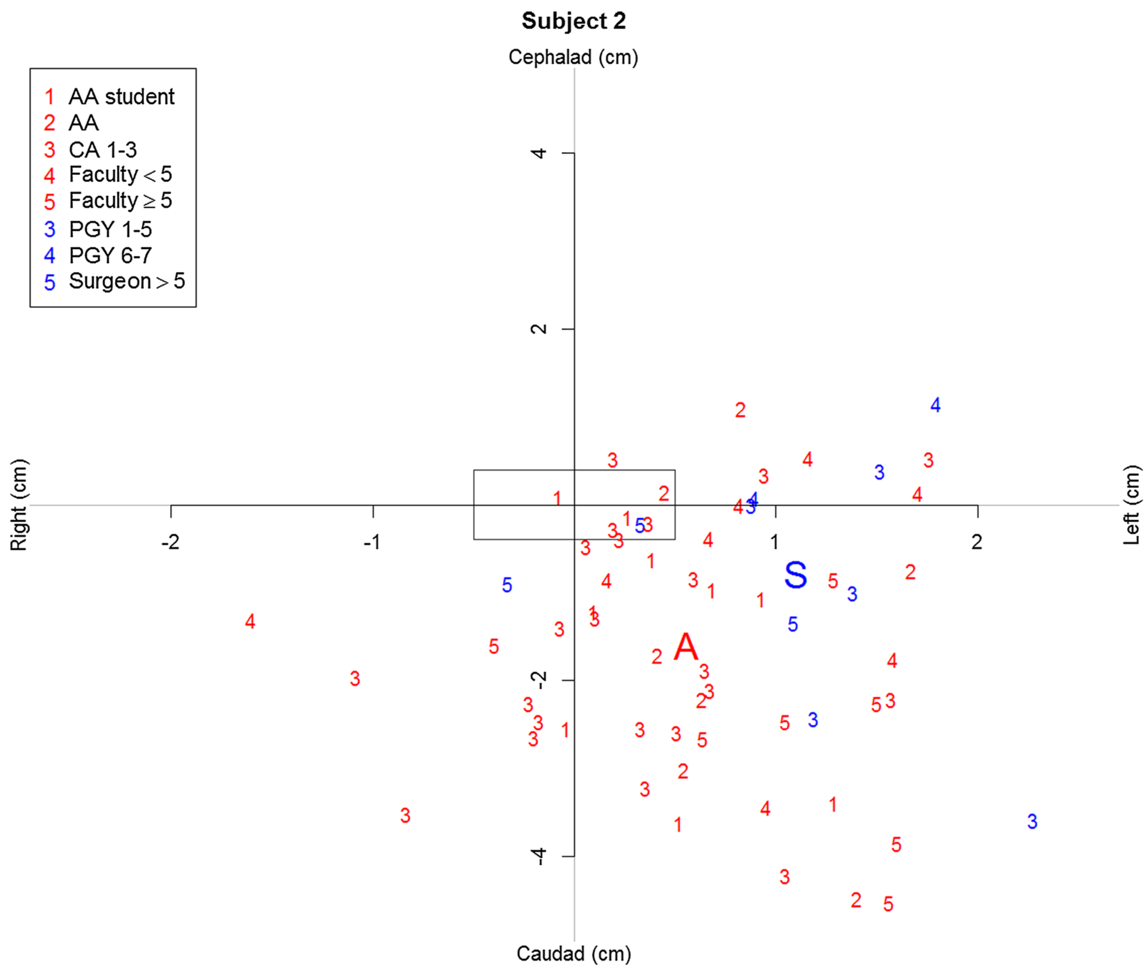

Fig. 3 Scatterplot of participant markings for Subject 2. Numbers represent specific training levels for participant groups. Red denotes anesthesia providers and blue denotes surgeons. For all subjects, success is defined as an absolute x-value 0.5 (within 5 mm of the sagittal midline),[13,15] with an absolute y-value defined by the ultrasonically measured CTM height/2. Success is defined as an absolute y-value 0.4. The letters "A" and "S" in each scatterplot denote the mean x- and y-values, respectively, for anesthesia providers and surgeons. Notice the leftward lateralization of the mean values for both anesthesia providers and surgeons. CTM = cricothyroid membrane

providers and surgeons. For all subjects, success was defined as an absolute x-value within 5 mm of the sagittal midline, [13,15] with an absolute y-value defined by the ultrasound measurement of the CTM height/2.

Table 5 displays the success rates by participant group for participants with and without experience performing a surgical airway. Three of 18 surgeons who had previously performed a surgical airway successfully identified the CTM in at least two of the subjects. Only one of these three surgeons correctly identified the CTM location in three test subjects, and no surgeon correctly identified the CTM in all four test subjects.

Discussion

The primary outcome of this study revealed low and not significantly different successful CTM identification rates for both anesthesia providers and surgeons collectively as well as for various levels of training. Our secondary outcome showed that there was no significant difference in the success rate of CTM identification based on either clinical experience following residency or emergency surgical airway experience.

Compared with prior studies,[13,15,16] anesthesia provider CTM identification success rates in our study were lower in the three non-obese female test subjects with varying measurements of neck anatomy and similar in the morbidly obese test subject. The success rates were similarly low for the surgeon participants.

Notably, in both participant groups, the average CTM identification location for Subject 2 showed a leftward lateralization from the midline that was not evident in other studies of anesthesia providers.[13,15,16] Variation in neck anatomy measurements may provide an explanation for this discrepancy. Indeed, Aslani *et al.* reported a mean

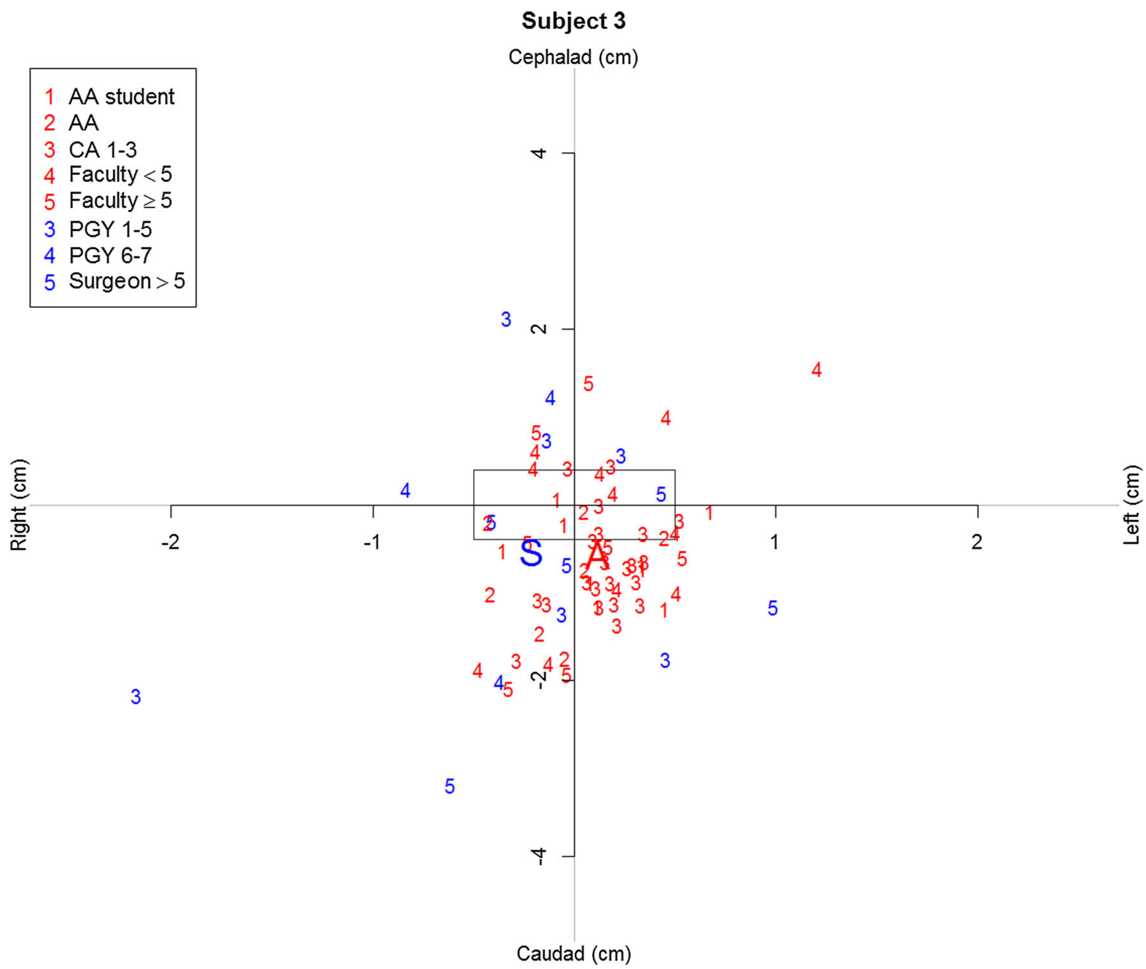

Fig. 4 Scatterplot of participant markings for Subject 3. Numbers represent specific training levels for participant groups. Red denotes anesthesia providers and blue denotes surgeons. For all subjects, success is defined as an absolute x-value 0.5 (within 5 mm of the sagittal midline),[13,15] with an absolute y-value defined by the ultrasonically measured CTM height/2. Success is defined as an absolute y-value 0.4. The letters "A" and "S" in each scatterplot denote the mean x- and y-values, respectively, for anesthesia providers and surgeons. CTM = cricothyroid membrane

(standard deviation) SMD in non-obese and obese females of 19.1 (2.2) cm and 18.8 (2.5) cm, respectively.[13] Subject 2 had an SMD of 12.7 cm, suggesting that a comparatively shorter neck and corresponding smaller space for palpation might result in less successful CTM identification.

Another variation of neck measurement in our study that may have explained the low rates of successful CTM identification is the TMD/SMD ratio. This ratio estimates the location of the larynx in the neck. The lower the ratio, the more cephalad the location of the larynx in the neck. We hypothesize that CTM palpation becomes more difficult with greater cephalization. The reduced space between the hyoid bone and larynx increases the likelihood of confusing the thyroid and cricoid cartilages. The TMD/SMD ratios in the Aslani study were 0.48 and 0.46 in non-obese and obese females, respectively,[13] whereas Subject 4 (non-obese female) in our study had a TMD/SMD ratio of 0.36, indicating a minor cephalization of the larynx compared with the Aslani study.

Despite most surgeons' greater experience in performing surgical airways and their higher self-rated confidence and ability, their success rates of CTM identification were comparable with those of the anesthesia providers.

Another novel finding was that prior experience in creating an emergency surgical airway did not result in significantly greater rates of CTM identification. For example, the only participant who correctly identified the CTM in all four subjects was a first-year CA resident with no clinical surgical airway experience. This apparent incongruity in our study between surgeons' successful surgical airway performance and their low CTM identification success rates may be partially explained by surgeons' more frequent use of open tracheostomy techniques[7] that do not rely on skin palpation. An open

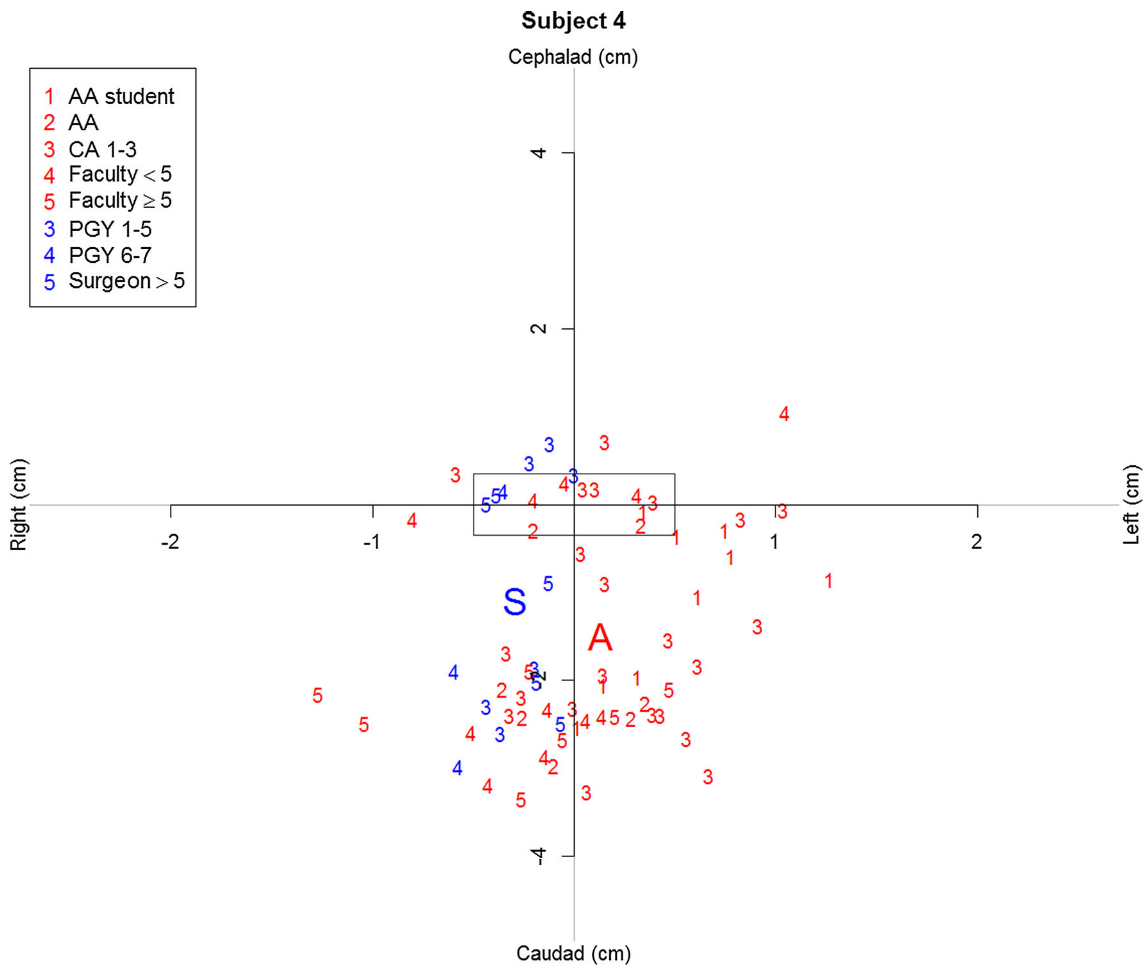

Fig. 5 Scatterplot of participant markings for Subject 4. Numbers represent specific training levels for participant groups. Red denotes anesthesia providers and blue denotes surgeons. For all subjects, success is defined as an absolute x-value 0.5 (within 5 mm of the sagittal midline),[13,15] with an absolute y-value defined by the ultrasonically measured CTM height/2. Success is defined as an absolute y-value 0.35. The letters "A" and "S" in each scatterplot denote the mean x- and y-values, respectively, for anesthesia providers and surgeons. CTM = cricothyroid membrane

Table 3 Participants' successful attempts at identifying the cricothyroid membrane of four test subjects

All Participants				
Test Subject	Success rate, *n*/N (%)			
	Anesthesia providers	Surgeons	Absolute percentage difference (95% CI)	*P* value
1	11/57 (19)	6/12 (50)	−31(−60 to 1)‡‡	0.06‡
2	6/53 (11)	1/10 (10)	1 (−32 to 34)‡‡	1.00‡
3	10/56 (18)	2/14 (14)	4 (−26 to 33)‡‡	1.00‡
4	9/56 (16)	4/14 (29)	−13 (−42 to 18)‡‡	0.28‡
All test subjects	36/222 (16)	13/50 (26)	−10 (−23 to 3)**	0.15*

CI = confidence interval. ‡*P* values obtained by Fisher's exact test (*P* value < 0.0125 considered significant after Bonferroni correction).**P* value obtained by Chi square test (*P* value < 0.0125 considered significant after using Bonferroni correction). ‡‡CI obtained by the exact method. **CI obtained by the standard Wald asymptotic method

cricothyrotomy technique involves using a scalpel to make a skin incision over the general presumed location of the CTM. Subsequent blunt digital dissection corrects for errors in skin palpation, allowing CTM identification either visually or by direct palpation. Recent literature suggests significantly higher success rates for open *vs* needle

Table 4 Successful attempts of participants at training levels 3, 4, and 5 at identifying the cricothyroid membrane of four test subjects

Test Subject	Success rate, *n*/N (%)			
	Anesthesia providers	Surgeons	Absolute percentage difference (95% CI)	*P* value
Training Level 3				
1	4/23 (17)	2/6 (33)	−16 (−59 to 28)	0.58
2	3/22 (14)	0/5 (0)	14 (−35 to 60)	1.00
3	3/22 (14)	0/6 (0)	14 (−31 to 56)	1.00
4	3/22 (14)	1/6 (17)	−3 (−48 to 42)	1.00
Training Levels 4 and 5				
1	4/18 (22)	4/6 (68)	−44 (−82 to 5)	0.13
2	0/15 (0)	1/5 (20)	−20 (−72 to 33)	0.25
3	2/18 (11)	2/8 (25)	−14 (−53 to 28)	0.56
4	3/18 (17)	3/8 (38)	−21 (−59 to 20)	0.33

CI = confidence intervals obtained by the exact method. *P* values were obtained by Fisher's exact test ($P < 0.0125$ considered significant after using Bonferroni correction)

Table 5 Participants' successful attempts at identifying the cricothyroid membrane of four test subjects based on experience creating surgical airways

Test Subject	Success rate, *n*/N (%)			
	Anesthesia providers	Surgeons	Absolute percentage difference (95% CI)	*P* value
No Experience Creating Surgical Airways				
1	10/50 (20)	0/3 (0)	20 (−45 to 74)	1.00
2	6/47 (13)	0/2 (0)	13 (−67 to 84)	1.00
3	10/49 (20)	0/3 (0)	20 (−44 to 73)	1.00
4	8/49 (16)	1/3 (33)	−17 (−71 to 47)	0.44
Experience Creating Surgical Airways				
1	1/7 (14)	6/9 (67)	−52 (−85 to 1)	0.06
2	0/6 (0)	1/8 (13)	−13 (−61 to 41)	1.00
3	0/7 (0)	2/11 (18)	−18 (−60 to 28)	0.50
4	1/7 (14)	3/11 (27)	−13 (−56 to 34)	1.00

CI = confidence intervals obtained by the exact method. *P* values were obtained by Fisher's exact test (*P* value < 0.0125 considered significant after using Bonferroni correction)

cricothyrotomy (67% by battlefield medics,[4] 85% by battlefield physicians,[4] 100% by the London air ambulance service[5]).[7] Our study may help to explain this disparity, i.e., reliable accurate identification of the CTM in females may not be possible by skin palpation, even by trauma surgeons with expert procedural skills. Performing a surgical airway with an open *vs* a percutaneous technique not only achieves higher success rates but also accomplishes the procedure in nearly half the time.[21]

Based on this study and findings in recent literature,[22-25] we propose that clinicians should always pause before proceeding with an open cricothyrotomy to enable better identification of the anatomy within the initial wound. Although ultrasonography may be ideal for identifying the CTM,[26] we cannot assume its availability and universal clinical applicability, and therefore, it is not included in this discussion.

There were several limitations to this study, including the small number of surgeons relative to anesthesia providers in the convenience sample and the non-standardization of photographic technique for which we generated and applied a correction factor. Nevertheless, the results of this study are significant and highlight the importance of performing a surgical cricothyrotomy for emergency invasive airway access in adults. Our recommendations are consistent with the most recent "Difficult Airway Society guidelines for management of unanticipated difficult intubation in adults".[27]

In conclusion, this study adds several important findings to the current literature. First, the success rate of both anesthesia providers and trauma surgeons for identifying

CTM by palpation was ≤ 50%, even in non-obese females with optimized neck extension. Second, our study did not show significant differences in the success rates of CTM identification based on either clinical experience following completion of residency or prior emergency surgical airway experience.

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