tracheal intubation was in the same range as reported earlier.[5]

A limitation of the study is that it is a single centre study and all iLTS-D insertions and tracheal intubations were performed by a single clinician. None of the patients had predictors of difficult airways or a known history of airway complications, so the performance of the iLTS-D in patients with difficult airways remains unknown. Finally, the study was observational and non-comparative.

This observational study assessed the feasibility of blind intubation through the iLTS-D. Insertion and ventilation through the iLTS-D were easy in all patients. Blind intubation was possible in only 32% of the cases. All other patients were intubated after correction manoeuvres or with fibreoptic guidance. Because of this low blind intubation success rate, we recommend the use of a fibreoptic scope to facilitate intubation through the iLTS-D and to avoid airway trauma [additional material of the following videos: Blind Intubation Non-guided (identifier number of the video 6, http://links.lww.com/EJA/A292); Blind Intubation With Rotation Manoeuvres (video identifier 15, http://links.lww.com/EJA/A294); Guided Intubation (video identifier 8, http://links.lww.com/EJA/A293)].

Acknowledgements relating to this article

Assistance with the letter: We would like to thank Julio Florentino del Corral for his assistance with statistical analyses and Pablo Roza and María Rabanal for their help with the writing and layout of the final manuscript.

Financial support and sponsorship: none.

Conflicts of interest: none

References

1 Wiese CHR, Semmel T, Müller JU, *et al.* The use of the laryngeal tube disposable (LT-D) by paramedics during out-of-hospital resuscitation-An observational study concerning ERC guidelines 2005. *Resuscitation* 2009; **80**:194–L198.
2 Keller C, Brimacombe JR, Keller K, Morris R. Comparison of four methods for assessing airway sealing pressure with the laryngeal mask airway in adult patients. *Br J Anaesth* 1999; **82**:286–287.
3 Kleine-Brueggeney M, Theiler L, Urwyler N, *et al.* Randomized trial comparing the i-gelTM and Magill tracheal tube with the single-use ILMATM and ILMATM tracheal tube for fibreoptic-guided intubation in anaesthetized patients with a predicted difficult airway. *Br J Anaesth* 2011; **107**: 251–257.
4 Cook TM, Gatward JJ, Handel J, *et al.* Evaluation of the LMA Supreme in 100 nonparalysed patients. *Anaesthesia* 2009; **64**:555–562.
5 Bergold MN, Kahle S, Schultzik T, *et al.* Intubationslarynxtubus suction disposable. *Anaesthesist* 2016; **65**:30–35.
6 Somri M, Vaida S, Garcia Fornari G, *et al.* A randomized prospective controlled trial comparing the laryngeal tube suction disposable and the supreme laryngeal mask airway: the influence of head and neck position on oropharyngeal seal pressure. *BMC Anesthesiol* 2016; **16**:87.

DOI:10.1097/EJA.0000000000001213

OPEN

Cricothyroid membrane identification with ultrasonography and palpation in cadavers with a novel fixation technique (Fix for Life)

A laboratory investigation

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Editor,

Emergency front-of-neck access (eFONA) to the airway by performing a cricothyroidotomy is the last resort in a ‘can’t intubate can’t oxygenate’ situation.[1] The crucial initial step in this procedure is the correct identification of the cricothyroid membrane (CTM). Particularly in female patients, the traditional palpation method has proved challenging.[2] The use of ultrasonography in locating the CTM is promising and may increase the success rate, but evidence is yet conflicting.[3] Using ultrasonography preprocedurally in elective anaesthesia cases has been propagated as a standard operational procedure to identify and mark the CTM when inspection or palpation of landmarks is difficult.[4]

The training of cricothyroidotomy in the clinical setting is difficult because the incidence is low, and the acute setting is not appropriate to train this procedure. Mannequins and animals serve as training models, but they do not closely reflect human anatomy nor its variance. Using recently deceased patients is not always ethical and fresh frozen human cadavers of body donors to science have time constraints, due to ongoing putrefaction. Formalin-fixed cadavers become very firm and inflexible.[5]

Recently, Fix for Life (F4L) embalmed cadavers have been described to be suitable and realistic in the training of basic airway management techniques, without the above disadvantages.[5] The F4L cadaver could also be appropriate to train in identification of the CTM. In the current study, the primary aim was to determine if anaesthesiology participants would judge the F4L cadaver ‘suitable’ (assessment of suitability for learning) and

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'realistic' (assessment of look, feel and flexibility compared with a living human) as a teaching model in locating the CTM by palpation or ultrasonography. Second, we compared success rates and time required to identify the CTM.

Ethical approval was provided by the Medical Ethics Review Committee of VU University Medical Center (Amsterdam, the Netherlands. Reference 2018.429) on 13 August 2018 (Chairperson Prof C. Boer). Because of the more challenging anatomy concerning the identification of the CTM, three female cadavers were used.[2] Age at death, weight, length, BMI and neck circumference were recorded. Cadavers of body donors with known neck abnormalities (e.g. tumour masses, goitre) or surgical procedures (including eFONA) were excluded. In each cadaver, the head was placed in the extended position and the correct CTM location was marked with a dot of invisible ink, becoming visible only under ultraviolet (UV) light.

Forty anaesthesiologists and trainees participated after informed consent. Each participant received a brief training in ultrasonography-aided identification of the CTM.[4] The participants were then allowed to practise the ultrasonography techniques on a F4L cadaver which was not included in the study. Each participant was randomly allocated to either the palpation group or the ultrasonography group using a sealed envelope technique. After randomisation, the participants were asked to identify the CTM in the three cadavers and to mark their localisation with a blunt anatomical probe.

The time required to identify the CTM was recorded. Successful identification of the CTM was defined as 'positive' if the participants' probe mark lay within 5 mm of the predefined location after cross-checking using UV light. The participants were asked to classify the difficulty of identifying the CTM using an established four-grade system (1, easy/visible landmarks; 2, moderate/requires light palpation of landmarks; 3, difficult/requires deep palpation of landmarks; or 4, impossible/landmarks are not palpable).[6] This procedure was repeated for each of the three cadavers in the same order. After completion of the procedures on all three cadavers, the participants of both groups were asked to give one overall verbal rating score (VRS) (1, worst score; 10, best score) for 'realism' and one for 'suitability' of the F4L cadaver model.

We based the sample size estimation on the obtainable width of the two-sided 95% confidence interval (CI) for the estimation of 'realism' and 'suitability' (primary outcomes), and considered a margin of error of no more than 1 (total width of the CI no larger than 2) as acceptable precision. Assuming normal distribution of the data and an expected SD of 2, we therefore required 18 participants in each group. Accounting for possible dropouts, we aimed at 20 participants in each group. The calculation was performed with PASS 16 (NCSS Statistical Software, Kaysville, Utah). Generalised estimating equations were used to compare the groups for the primary and secondary outcomes, with professional level and experience as covariates. Significance was set at a P value of 0.05.

Table 1 Characteristics of the three female Fix for Life cadavers

	Cadaver 1	Cadaver 2	Cadaver 3
Age at death (years)	68	90	75
Weight (kg)	52	66	61
Length (m)	1.70	1.67	1.66
BMI (kg m^{-2})	18.0	23.7	22.1
Neck circumference (cm)	42	52	38

All participants completed the experimental tasks in all three cadaver models, resulting in a total of 120 attempts, that is 60 attempts per group. Characteristics of the cadavers are shown in Table 1. VRS for realism and suitability, success percentages in locating the CTM, time to identify the CTM, difficulty scores and characteristics of the participants are shown in Table 2.

The F4L cadaver model received high VRS scores for both 'realism' and 'suitability' as a teaching model for the localisation of the CTM by palpation and these scores were even higher for the ultrasonography technique. The identification of the CTM using ultrasonography in F4L cadavers was more successful compared with digital palpation (success rate 91.7 versus 70.0%, $P=0.011$). However, the time to identify the CTM was markedly longer in the ultrasonography group. The identification of the CTM in cadavers with a larger neck circumference were rated as easier by participants in the ultrasonography group, presumably as more pretracheal soft tissue helps focus the ultrasonographic beam.[2]

A limitation of the study was the imbalance in baseline characteristics of the participants; however, this had no

Table 2 Verbal rating scores for realism and suitability of the Fix for Life cadaver model, success rates of locating the cricothyroid membrane, mean time to identify the cricothyroid membrane, difficulty scores and grade and years of professional experience of the participants in the ultrasonography and palpation groups

	US group	PAL group	P
VRS realism	8 (8 to 9)	8 (7 to 8)	0.001
VRS suitability	8.5 (8 to 10)	8 (8 to 8)	0.030
Success in locating CTM, n	55 (91.7%)	42 (70.0%)	0.011
Time to identify CTM (s)	34.3 (21.4 to 47.2)	12.0 (8.8 to 15.2)	<0.001
Difficulty score, median [IQR]			
Cadaver 1	2 [1 to 3]	2.5 [2 to 3]	0.014
Cadaver 2	2 [2 to 2]	3 [2 to 3]	<0.001
Cadaver 3	2 [1.25 to 2.75]	2 [2 to 2.75]	0.315
Consultant/trainee	16/4	10/10	0.663*
Professional experience (years)	12.3 ± 7.1	11.1 ± 8.9	0.149*

Values are median (95% CI), median [IQR], number (n), number (%), mean time (95% CI) or mean ± SD. CTM, cricothyroid membrane; PAL, palpation; US, ultrasonography; VRS, verbal rating scores. *For the comparison of baseline covariates, the absolute standardised mean difference rather than the P value is reported.

significant effect on the outcomes. Moreover, sample sizes were not calculated for between-group comparisons and therefore these data should be regarded as preliminary. Complications in eFONA, such as excess time, incision errors, tube misplacements, haemorrhage and cartilage injury, warrant adequate training and the upkeep of skill for this procedure.[7] Since the correct identification of the CTM is recognised as the critical initial step, and since gaining confidence in one's ability to correctly identify the CTM may decrease the barrier to perform cricothyroidotomy when indicated, we suggest that training with the F4L cadaver model contributes to a timely, correct application of cricothyroidotomy in the future.

Acknowledgements relating to this article

Assistance with the letter: we would like to thank Jasmina Rubira Yoxall and Eliane Kaaij, anatomy laboratory staff of the department of Anatomy and Neurosciences, for their co-operation during this study.

Financial support and sponsorship: none.

Conflicts of interest: none.

References

1 Frerk C, Mitchell VS, McNarry AF, *et al.* Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *Br J Anaesth* 2015; **115**:827–848.
2 Aslani A, Ng SC, Hurley M, *et al.* Accuracy of identification of the cricothyroid membrane in female subjects using palpation: an observational study. *Anesth Analg* 2012; **114**:987–992.
3 Yildiz G, Goksu E, Senfer A, *et al.* Comparison of ultrasonography and surface landmarks in detecting the localization for cricothyroidotomy. *Am J Emerg Med* 2016; **34**:254–256.
4 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–i48.
5 van Emden MW, Geurts JJ, Schober P, *et al.* Comparison of a novel cadaver model (Fix for Life) with the formalin-fixed cadaver and manikin model for suitability and realism in airway management training. *Anesth Analg* 2018; **127**:914–919.
6 Nicholls SE, Sweeney TW, Ferre RM, *et al.* Bedside sonography by emergency physicians for the rapid identification of landmarks relevant to cricothyrotomy. *Am J Emerg Med* 2008; **26**:852–856.
7 Bair AE, Panacek EA, Wisner DH, *et al.* Cricothyrotomy: a 5-year experience at one institution. *J Emerg Med* 2003; **24**:151–156.

DOI:10.1097/EJA.0000000000001230

The use of three-dimensional printing and virtual reality to develop a personalised airway plan in a 7.5-year-old child

A case report

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Editor,

Computer-assisted design programmes make anatomically correct models from a patient's computed tomography (CT) images. This model can be printed on a three-dimensional printer or turned into a virtual reality programme used with commercially available headsets. To date, the use of three-dimensional printing in anaesthesia has been mainly for educational purposes.[1]

Lung isolation for one-lung ventilation (OLV) can be challenging. In paediatric patients, the range of equipment available is limited. The smallest double-lumen tube (DLT) commercially available is 26 French gauge (FG), with an external diameter of 8.6 mm.[2] Although it is not generally recommended in children younger than 8 years of age, there are case reports in younger children.[3]

Despite extensive adult experience, our familiarity with OLV in the very young paediatric population is limited. We were presented with a 7.5-year-old 18-kg child scheduled for right upper lobectomy due to lung metastasis from a Ewing's sarcoma. We used a combination of three-dimensional printing and virtual reality bronchoscopy to develop a personalised airway plan reducing the potential for trial and error in airway manipulation.

The patient's family consented to the publication of this report.

The three-dimensional model was developed by identifying the trachea, main bronchi and lobar bronchi from an existing CT scan (IntelliSpace Portal v11; Philips Healthcare, Best, The Netherlands). The images were imported into postprocessing software (3-matic medical 14.0; Materialise, Leuven, Belgium). The walls of the model built outwards to maintain the internal diameter and hollowed out so that we could test OLV. The model was then printed in clear plastic (PolyJet J750; Srtatasys, Rehovot, Israel), and converted into a virtual reality program (D2P; 3D Systems, Rock Hill, California, USA; Vive; HTC, Taoyuan, Taiwan; SteamVR; Valve Corporation, Bellevue, Washington, USA) to allow a virtual bronchoscopy to be performed.

The CT measurements were reassuring for use of a 26-FG DLT (tracheal diameter 9 mm) but not for a bronchial blocker [distance from the right upper lobe bronchus (RULB) to the carina 9.4 mm] (Fig. 1a). Prior to using the model our airway plan was

(1) A: 26-FG DLT (Teleflex, Morrisville, North Carolina, USA);
(2) B: 5-mm microlaryngeal tube (MLT) (Smiths Medical, Dublin, Ohio, USA).

The day before surgery, the treating anaesthesiologist (VV) spent time on the virtual reality simulator familiarising himself with the patient's airway anatomy (Fig. 1b).