**Editor’s key points**

- Obesity and airway burns are risk factors for failed tracheal intubation.
- Percutaneous tracheal access is required in ~40% of airway emergencies, but failure rates are high.
- The authors modified standard airway manikins to simulate the airways of obese and burned patients.
- In airway emergency simulations modified manikins better simulated reality than standard manikins.

**Background.** Percutaneous tracheal access is required in more than 40% of major airway emergencies, and rates of failure are high among anaesthetists. Supraglottic airway management is more likely to fail in patients with obesity or neck pathology. Commercially available manikins may aid training. In this study, we modified a standard ‘front of neck’ manikin and evaluated anaesthetists’ performance of percutaneous tracheal access.

**Methods.** Two cricothyroidotomy training manikins were modified using sections of belly pork to simulate a morbidly obese patient and an obese patient with neck burns. An unmodified manikin was used to simulate a slim patient. Twenty consultant anaesthetists were asked to manage a ‘can’t intubate, can’t ventilate’ scenario involving each of the three manikins. Outcome measures were success using their chosen technique and time to first effective breath.

**Results.** Success rates using first-choice equipment were: ‘slim’ manikin 100%, ‘morbidly obese’ manikin 60%, and ‘burned obese’ manikin 77%. All attempts on the ‘slim’ manikin succeeded within 240 s, the majority within 120 s. In attempts on the ‘morbidly obese’ manikin, 60% succeeded within 240 s and 20% required more than 720 s. All attempts on the ‘burned obese’ manikin succeeded within 180 s.

**Conclusions.** Significantly greater technical difficulty was experienced with our ‘morbidly obese’ manikin compared with the unmodified manikin. Failure rates and times to completion were considerably more consistent with real-life reports. Modifying a standard manikin to simulate an obese patient is likely to better prepare anaesthetists for this challenging situation. Development of a commercial manikin with such properties would be of value.

**Keywords:** airway management; obesity; tracheostomy; training

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may not prepare clinicians for more challenging situations, particularly performing emergency percutaneous tracheal access in the obese or morbidly obese, or in patients with significant head and neck pathology.

In this study, we have used standard and modified airway manikins to compare their utility in simulating emergency percutaneous tracheal access in obese or burned patients.

**Methods**

This was a prospective, observational study to evaluate the utility of novel manikins in simulating airway management. Approval for the project was granted by the Trust’s research and development department. Ethical approval was not requested.

**Subjects and simulation**

All 20 consultant anaesthetists in our department, not otherwise involved in the study, were enrolled in the study. The investigators provided written information regarding the study purpose and process, and each subject gave written consent before participating. Subjects completed a short questionnaire designed to determine their prior experience in percutaneous tracheal access in elective and emergency situations, and also how recently they had received training in these techniques.

Each subject was then presented with a clinical scenario for the simulation exercise, constituting a ‘can’t intubate, can’t ventilate’ (CICV) situation which required emergency percutaneous tracheal access. The key elements of the scenario are presented in Table 1. They were then asked to volunteer what equipment they would call for in this situation, when managing each of three different hypothetical patients: (i) a slim patient (BMI 25 kg m\(^{-2}\)) with no head or neck burns; (ii) a morbidly obese patient (BMI 50 kg m\(^{-2}\)) with no head or neck burns; and (iii) an obese patient (BMI 30 kg m\(^{-2}\)) with deep full-thickness burns and eschar on the anterior aspect of the neck. If the subject felt unable to volunteer equipment choices, they were offered the equipment available in our hospital for three different techniques: a 13 G Ravussin cannula and Manujet (VBM GmbH, Sulz, Germany) for tracheal cannulation and high-pressure source ventilation; a 5.0 mm cuffed Melker emergency cricothyroidotomy catheter set (Cook Medical, Bloomington, IN, USA); and equipment for a ‘surgical’ airway comprising a handle-mounted size 20 scalpel blade, a gum-elastic bougie, tracheal spreaders, a tracheal hook, and a size 6.0 mm cuffed tracheal tube. A self-inflating bag was provided for ventilation where the Melker and surgical techniques were chosen.

Each candidate was then asked to perform emergency percutaneous tracheal access within the simulation scenario, on each of the three hypothetical patients, using their chosen equipment. Each manikin was concealed until the moment the simulation began, at which point a timer was started. Candidates were allowed to change to either of the other two equipment choices at any point, and were told when 3 min had elapsed. The timer was stopped at the first delivery of an effective breath, giving an overall time for success. In addition, split times were recorded when a candidate made a change to their equipment, enabling measurement of time taken for each technique and choice.

The three manikins were presented in a randomized order to minimize the chance of rehearsal bias. Randomization was performed by the investigators using a web-based random number generator (https://www.random.org): each manikin was assigned a ‘magnitude’ (lowest number = ‘slim’ neck; middle number = ‘morbidly obese’ neck; highest number = ‘burned obese’ neck) then three random numbers were generated in sequence. The order of the sequence determined the order in which the manikins were presented. Randomization was concealed from participants. Each subject was supplied with standard personal protective equipment.

**Materials**

Three cricothyroidotomy training manikins were used in this study:

(i) ‘Slim neck manikin’: The unmodified manikin, manufactured by Pharmabotics Ltd (Hampshire, UK), is shown in Figure 1. Key components are a plastic head, neck, and upper torso, housing a soft plastic trachea encased in harder plastic rings (simulating cartilage), with soft synthetic skin and subcutaneous tissue.
overlying. Thickness of this latter tissue is \( \approx 3 \) mm and landmarks (thyroid cartilage, cricothyroid membrane) are readily palpable. The manikin was used in its unmodified form to simulate the slim patient.

(ii) ‘Morbidly obese neck manikin’: A thick slice of belly pork [mean (SD) 3.7 (0.3) cm, range 3.3–4.5 cm] was laid over the trachea in place of the synthetic skin, to simulate the morbidly obese patient (Fig. 2). The belly pork was held in place with suture material around the trachea, and red-tinted chlorhexidine/alcohol solution was infiltrated subcutaneously using a 25 G spinal needle to simulate blood (Fig. 3). The housing was replaced and the manikin held together using tape (to account for the additional thickness).

(iii) ‘Burned obese neck manikin’: To simulate an obese patient with burns to the neck, a thinner slice of belly pork (\( \sim 1-1.5 \) cm with the meat and some of the fat removed) was charred with a blowtorch and attached to the manikin in the same way (Fig. 4).

In all three manikins, a balloon was taped over the caudal end of the trachea, to enable detection of an effective breath via inflation.

Outcomes

Outcome measures were success with first-choice equipment and time to first effective breath. For simulations in which candidates changed equipment, we also recorded time to successful airway placement using second-choice equipment. The null hypothesis for each measure was that there would be no difference between the three manikins. Failed attempts were allocated a time equal to the longest attempt plus 30 s.

Statistical analysis was performed using SPSS 21 (IBM Corp., New York, NY, USA); \( P<0.05 \) was taken to denote statistical significance. No power study was performed: 20 subjects were tested as this was the number of senior anaesthetists in the department. Only 13 of 20 subjects underwent simulation using the ‘burned obese’ manikin as this was added to the study protocol after recruitment had begun.

All subjects were asked to give feedback regarding usefulness after the simulation exercises.

Results

Twenty participants attempted both the ‘slim’ and ‘morbidly obese’ manikins, 13 of whom also attempted the ‘burned obese’ manikin. Integrity of the three manikins was maintained throughout and no simulation was abandoned.

Regarding prior experience of emergency percutaneous tracheal access, 16 participants had undertaken simulation training in the 12 months before the study, and 10 within the last 3 months. Eight of 20 had prior experience of percutaneous tracheal access in an emergency clinical setting and 19 of 20 had prior experience in an elective setting. The one subject who had no prior clinical experience had undertaken simulation training within 3 months of the study.
Success using first-choice equipment

Success rates for attempts using first-choice equipment are shown in Figure 5. Success rates with each manikin were as follows: ‘slim’ 20 of 20 (100%); ‘morbidly obese’ 12 of 20 (60%); and ‘burned obese’ 10 of 13 (77%). McNemar’s test showed a significant difference between ‘slim’ and ‘morbidly obese’ ($P = 0.008$) and no differences between ‘slim’ and ‘burned obese’ ($P = 0.250$) or ‘morbidly obese’ and ‘burned obese’ ($P = 0.375$).

We observed that the techniques with the lowest success rates were Ravussin in the ‘morbidly obese’ manikin and surgical in the ‘burned obese’ manikin. Because of the small numbers of participants with each technique, we did not perform statistical analyses.

Time to first effective breath

Times taken to deliver an effective breath with each manikin were as follows (Fig. 6): ‘slim’ 17 of 20 (85%) successful ≤ 120 s, and all ≤ 240 s; ‘morbidly obese’ 12 of 20 (60%) successful in ≤ 240 s, five (25%) requiring > 540 s, four (20%) > 720 s including one failure; ‘burned obese’ manikin 12 of 13 (92%) successful ≤ 120 s and all ≤ 180 s.

Related samples Friedman’s test showed significant differences in times to first breath across the three models ($P < 0.0005$). Related samples Wilcoxon signed-ranks tests were then used to analyse these differences: times to first breath differed significantly between ‘slim’ and ‘morbidly obese’ (median 72 vs 183.5 s, $P = 0.001$) and between ‘morbidly obese’ and ‘burned obese’ (median 183.5 vs 71 s, $P = 0.001$). There was no difference between ‘slim’ and ‘burned obese’ ($P = 0.576$).

Attempts with second-choice equipment

As all attempts were successful in the ‘slim’ manikin, no attempts were made with second-choice equipment. Eight attempts using second-choice equipment were required in the ‘morbidly obese’ manikin [median (so) time to success 305 (159) s, range 71–511 s] and three in the ‘burned obese’ manikin [median (so) time to success 100 (41) s, range 41–120 s]. Because of the small numbers of participants with each technique, we did not perform statistical analyses.

Of eight attempts using second-choice equipment in the ‘morbidly obese’ model, seven were successful: five using a surgical approach, one with a Ravussin cannula, and one with a Melker set and some surgical tools. Of three attempts using second-choice equipment in the ‘burned obese’ model, two (67%) were successful using a Melker set and one (33%) with a Ravussin cannula.

Feedback

All 20 subjects commented on the enhanced realism of the obese manikins, with one subject commenting that it was the most useful airway training exercise they had ever undertaken. Many suggested that they would revise their preferred choice of technique when faced with this situation in future.

Discussion

NAP4 showed that serious airway morbidity occurs disproportionately in the obese and percutaneous tracheal access techniques fail frequently in the hands of anaesthetists. In NAP4, percutaneous tracheal access techniques were attempted in 80 patients, of whom 20 died or were permanently harmed. In
the anaesthetic cohort of 58 cases, airway rescue took < 5 min in 15% of cases, but more than 1 h in 19% of cases. Anaesthetists succeeded in securing the airway in only 36% of cases.\(^2\) Change of technique during attempted rescue was commonplace. In contrast, many manikin studies simulating percutaneous tracheal access techniques report 100% success and very short time periods.\(^8\) –\(^11\) The obese or burned airway poses a great challenge for airway rescue. The results of our simulation study are far more comparable with those seen in NAP4, and suggest that a modified manikin may be appropriate for realistically simulating the difficulty encountered when dealing with such patients in clinical practice.

Manikin studies of emergency percutaneous tracheal access (often comparing different techniques and equipment) report high success rates approaching 100%. Vadodaria and colleagues\(^8\) assessed four different techniques for emergency percutaneous tracheal access using a high-fidelity simulation manikin: two of the four techniques yielded 100% success with the median times of < 60 s, while the other techniques had between 80% and 100% success with some difficulty in positioning and longer times to completion (averaging 102 and 123 s). Sulaiman and colleagues\(^9\) reported 93% success in synthetic manikins when using a cuffed Melker set (96% using an uncuffed Melker set, 85% using a surgical technique). These outcomes suggest a low level of technical difficulty. Our study also showed 100% success rate in a ‘slim neck’ model, but in our ‘morbidly obese’ manikin, only 60% succeeded using their first-choice technique.

Manikin studies also report short times to completion, across a range of techniques and operators. Dependent on the technique/equipment used, Sulaiman and colleagues\(^9\) reported average insertion times between 44 and 88 s, and Vadodaria and colleagues\(^8\) reported averages of 38–123 s. Wong and colleagues\(^10\) using a Melker set, reported mean times to oxygen delivery as short as 23 s, with the longest average being 55 s; in a later study, from the same institution, average times to completion were 33 and 42 s.\(^11\) It is notable that the participants in these studies underwent repeated simulations (perhaps producing a ‘rehearsal effect’) using standard (‘slim neck’) manikins, and included inexperienced trainee participants. Our study included only experienced, trained participants and our data for the unmodified ‘slim neck’ manikin are fairly consistent with the above results (median 72 s). Similar timings have been documented in cadaveric human\(^6\)\(^,\)\(^12\)\(^,\)\(^13\) and animal\(^14\)–\(^16\) models. In contrast, the median time to first breath in our ‘morbidly obese’ manikin was far greater at 183.5 s.

Erzi and colleagues\(^17\) reported significantly thicker pre-tracheal tissue in morbidly obese patients who were difficult to intubate, compared with matched cases whose intubation was straightforward. Preoperative ultrasonography showed an average thickness of 33 mm in those who proved difficult to intubate, compared with 27 mm in those who were not. Neck circumference was also significantly greater in the difficult group. These and other findings\(^5\) suggest that patients with an obese neck may be both more difficult to intubate and more difficult to perform emergency percutaneous
tracheal access on, if required. It is logical that anaesthetists and other clinicians undertaking advanced airway management in obese patients should be trained to perform emergency percutaneous tracheal access in such patients: novel training manikins, for example, based on those we have described, would be of considerable potential value for this. A manufactured model with similar characteristics would be ideal.

The mean thickness of pork belly overlying the trachea in our modified ‘morbidly obese’ manikin was 37 mm—slightly greater than the 33 mm reported by Erzi and colleagues. Based on our clinical experience, we believe the increased thickness is reasonable—a patient who recently required emergency percutaneous tracheal access at our institution had a skin to trachea (minimum) distance of 49 mm measured radiographically. Given that the median time to first breath approached 200 s, and failure rate was 40% using our ‘obese’ manikin, we infer that training using unmodified manikins, cadavers and ‘wet’ animal models may lead to a false sense of confidence in managing CICV, and possibly an adoption of (and reliance on) one technique, whereas an alternative approach in real-world situations may be more likely to succeed.

Novel cricothyroidotomy manikins have been described previously. Dimitriadis and Paoloni18 designed their own manikin for a study comparing four percutaneous tracheal access techniques used by emergency physicians. However, an image published by this group suggests only a short distance from ‘skin’ to ‘trachea’, and this likely simulates a slim, uncomplicated patient. Heard and colleagues19 published their experiences over 4 yr of CICV simulation training in both ‘dry’ and ‘wet’ labs. Notably, their programme included simulation involving live anaesthetized sheep, with a ‘difficult anatomy’ scenario created by infusing 1000 ml of crystalloid into the sheep’s pre-tracheal soft tissue. In this model, cannula cricothyroidotomy was only successful in 40% of attempts, in keeping with our ‘morbidly obese’ manikin and with NAP4’s findings.2

We found no significant differences in success rates or insertion times between the ‘slim’ manikin and the ‘burned obese’ manikin. While this study is small and may not identify small differences in performance, it is more likely that the additional difficulty observed in our ‘morbidly obese’ model is attributable to increased tissue thickness (and that its absence creates unrealistic ease). The charring of our ‘burned’ model did not dramatically change the texture of the pig skin, and while a longer duration of charring may have produced something more reminiscent of pork ‘crackling’, we feel that this would not have relevance to clinical practice. This may be a limitation of our model that others might improve on.

Individual anaesthetists all started with their preferred technique, and likely had different skills and training in the three techniques making any comparison between these open to bias. It was not our main intention to study success rates or speed of different percutaneous tracheal access techniques, and in view of this potential bias and the small size of the study, we do not comment in any detail. The one notable observation is that when their first technique failed in the ‘morbidly obese’ manikin, the majority of participants used a surgical approach as their second choice and succeeded.

As far as we know, this study is the first attempt to modify synthetic cricothyroidotomy training manikins to simulate more challenging emergency percutaneous tracheal access. A strength of our study is selecting participants who were all highly experienced anaesthetists with recent experience or training in percutaneous tracheal access. Limitations include our completion of only 13 (not 20) simulations using our ‘burned obese’ manikin.

This study has shown that a group of 20 experienced consultant anaesthetists, with prior experience or training in percutaneous tracheal access, had notably lower success rates and took significantly longer to perform this procedure in a modified ‘morbidly obese’ cricothyroidotomy training manikin than in a standard ‘slim neck’ manikin. Failure rates and time taken are more consistent with those observed in real-life reports. Our results suggest that modifying a standard manikin to simulate an obese patient offers a greater level of difficulty and is likely to better prepare anaesthetists, and others, for CICV in circumstances they are most likely to encounter. It would be useful if a suitable commercial ‘obese neck’ manikin could be developed by industry.

Authors’ contributions

T.E.H. and C.A.L.: protocol design, simulation, data collection, statistical analysis, drafting of manuscript. F.E.K.: protocol design, critical revision of manuscript. T.M.C.: original idea, protocol design, statistical analysis, critical revision of manuscript.

Declaration of interest

The anaesthetic department at the Royal United Hospital Bath has previously received free or at cost airway equipment for evaluation or research. Cook Medical provided several Melker emergency cricothyroid catheter sets for this study. T.M.C. is an Associate Editor of the British Journal of Anaesthesia.

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