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Title

Observational, cadaveric study of emergency bystander cricothyroidotomy with a ball-point pen by untrained junior doctors and medical students.

Authors

Dr Andrew Neill (Corresponding Author)
Lecturer in Anatomy
Level 1, Biomedical Sciences Institute, Trinity College, Pearse St, Dublin 2
Ireland
(01) 8964329
andyneill81@gmail.com

Dr Philip Anderson
Foundation Year 2 Doctor, Northern Ireland Deanery.
UK

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ABSTRACT

Objective:

Apart from case-reports and anecdotes there are no published studies on the feasibility of using of non-medical devices for emergency bystander cricothyroidotomy. Our study evaluated the ability of non-trained junior doctors and medical students to place an emergency cricothyroidotomy on an embalmed cadaver using only a blade and a ball-point pen.

Methods:

Participants were junior doctors with no prior experience of surgical airways and second year medical students at the end of their head and neck anatomy course. Nine participants were asked to place an emergency cricothyroidotomy in an undissected embalmed cadaver using only a number 26 scalpel and a dismantled ball-point pen (*Papermate Flexigrip Ultra*, external diameter: 8.9 mm; internal diameter: 7.0 mm). Times were recorded and direct visualisation by dissection was used to assess placement and complications.

Results:

9 participants performed a total of 14 separate cricothyoroidtomies on separate cadavers. Landmarks were palpable by researchers in 10 out of the 14 cadavers. 8 out of 14 (57%) procedures were deemed successful. No major vascular injury occurred. Injuries to the thyroid and cricoid cartilages were common, 4 out of 14 (29%) of these injuries were fractures.

Conclusions:

In embalmed cadavers, inexperienced junior doctors and medical students with no prior training were able to place a successful cricothyroidotomy slightly more than half the time. It suggests that surgical cricothyroidotomy with a ball-point pen and blade is a feasible option in *extremis*. It is unknown whether junior doctors from other specialties such as emergency medicine would perform better.

INTRODUCTION

Acute upper airway obstruction is a rare but potentially lethal form of airway compromise. In the pre-hospital environment an emergency care provider may be required to place a primary surgical airway (ie without attempting direct laryngoscopy) in several situations outlined below.

One report in the military setting describes how combat medics are trained to place a cricothyoroidotomy following a failed supra-glottic airway placement in preference to direct laryngoscopy. [1]

In the civilian setting Paix et al describe a case series of pre-hospital surgical airways where a cricothyroidotomy was performed as a primary procedure either because of anatomic injury or lack of access to the airway in an entrapped patient. [2]

The final situation to consider a primary surgical airway in, would be as an emergency care provider required to intervene in an acute airway obstruction as a bystander without access to any typical advanced airway equipment. In such a situation standard airway maneuvers are unlikely to relieve a fixed obstruction at the level of the cords and if mouth-to-mouth ventilation is not possible then a primary surgical airway performed with improvised equipment may be required.

Virtually all studies of pre-hospital cricothyroidotomy use specifically designed medical devices. [2-4] One cadaveric study reports a method of improvised cricothyroidotomy using the spike of an intravenous fluid giving set as an improvised airway. [5] Only one case report describes the use of improvised, non-medical equipment. [6]

Theoretically any hollow structure with appropriate dimensions could be used as an improvised cricothyroidotomy. However, fictional depictions and some textbooks suggest the barrel of a ballpoint pen as a potential device. [7]

Owens *et al* [8] examined airflow dynamics of several different makes of ballpoint pen to establish which characteristics performed best when tested by a precision flowmeter.

However, the feasibility of actually placing a surgical cricothyroidotomy in a pre-hospital setting using improvised non-medical devices such as ballpoint pens has not been tested.

This study examined the ability of untrained junior doctors and medical students to place an emergency, surgical cricothyroidotomy in human cadavers using only a blade and a ballpoint pen.

METHODS

Procedures were performed on consecutive, unselected, undissected embalmed human cadavers from the department of anatomy, Trinity College Dublin, Ireland. Only one procedure was performed on each cadaver.

The ballpoint pen barrel used in this study was the *papermate flexigrip ultra medium.* (Figure 1.) We chose this pen as it was locally available and shared similar characteristics and dimensions to the optimal pen found in the study by Owens *et al*. [8]

The pen was dismantled and measurements were made of the barrel using calipers. Dimensions and characteristics are noted in Table 1.

Table 1 Characteristics of pen barrel.

External Diameter	8.9 mm
Internal Diameter	7.0 mm
Length	91.0mm
Internal ridging	None

Before participants entered the room, the ballpoint pen was disassembled and placed beside the blade. The cadaver was placed supine and the neck exposed and assessed by researchers as to whether the cricoid and thyroid cartilages were palpable. We provided a number 26 blade on a reusable scalpel handle. A fresh blade was used for each procedure. Participants were then asked to place an emergency cricothyroidotomy using the ballpoint pen barrel and blade provided as per the scenario outlined in Table 2.

Table 2 Participant instructions.

Clinical Scenario
You are eating in a restaurant when the person in the table next to you begins to choke on a piece of meat. Despite multiple attempts, the foreign body cannot be expelled and the person has now become unconscious and cyanosed. They are not breathing and mouth-to-mouth ventilation has no effect.
Instructions
Place a cricothyroidotomy using the dismantled pen and knife provided. **Do this as quickly as you feel you can.** When you are happy the pen is in the trachea let the researcher know. If you wish to abandon the procedure let the researcher know.

This was designed to reflect as much as possible a “real life” situation were the participant might have to place a cricothyroidotomy.

An example of appropriate final placement is shown in figure 2.

There were a total of 9 participants. 4 were junior doctors ranging from 1-4 years post graduation. 3 of these participants were beginning an 8-month post as anatomy demonstrators in the anatomy department of Trinity College Dublin. None had postgraduate experience of cadaveric head and neck anatomy. 4 participants were second year medical students who had just completed their course in head and neck anatomy. The final participant (AN) conceived the study and is an emergency medicine trainee and temporary anatomy lecturer. No participant had performed or observed an emergency cricothyroidotomy prior to this study. Participants were expected to perform the procedure with no specific training or advice on placement.

Procedure time was defined as the time from the participant entered the room until a) they were happy with the placement of the ballpoint pen barrel, b) the participant abandoned the procedure or c) 3 minutes had elapsed. No attempt was made to ventilate, as this was not feasible on embalmed cadavers.

Following each procedure the anterior neck was dissected to confirm placement by direct visualisation and document any anatomic injuries during the procedure. Information was recorded on a pre-designed form.

Injuries are reported as either ‘complete’ or ‘partial’. ‘Complete’ injury to a structure implied transection in the case of vessel, nerve or muscle, or fracture in the case of cartilaginous structures. ‘Partial’ injuries were defined as incomplete cuts to vessels, nerves or cartilage.

Significant vascular injuries were considered to be injuries to the common, internal and external carotid artery and their first order branches. Injuries to the internal jugular vein were also considered significant vascular injuries.

The ultimate extent of the dissection was dependant on the initial incision and placement of the pen barrel by the participant.

The primary outcome of the study was rate of successful placement of the pen barrel within the trachea. Although placement through the cricothyroid membrane was preferred as per table 2, we considered any placement in the trachea below the level of the vocal folds as a success.

Secondary outcomes were injuries to associated anatomical structures and time to placement.

RESULTS

The main results are summarised in table 3.

Table 3 Main Results

	Successful Procedures (n=8)	Unsuccessful Procedures (n=6)
Mean time taken (s) (± SD)	62 ± 33	93 ± 46
Landmarks Palpable	5	4
Mean Skin Incision (mm) (± SD)	26 ± 13.5	23 ± 5.6
Complete Cartilage Injuries	3	1
Complete Vascular Injuries	7	3
Complete Muscular Injuries	5	2

Cadavers were an average age of 82 at death and 9 of 14 (64%) were female. Weight was unavailable. Landmarks were deemed palpable by researchers prior to procedure, in 10 out of 14 cadavers.

9 participants performed a total of 14 cricothyroidotomies. Successful placement occurred in 8 out of 14 procedures (57%). One of these was an unintentional tracheostomy. No participant performed more than 2 procedures. When the participant's first procedure only was considered then participants were successful in 5 of 9 procedures (56%).

The mean time to end point in the successful group was 62 seconds (±33) and 93 seconds (± 46) in the unsuccessful group. Most (10 of 14) procedures involved horizontal incisions.

Injuries to anatomic structures were common and are summarised in table 4.

Table 4 Injuries to Anatomic Structures (n=14)

Vascular Structures	***Partial***	***Complete***
Inferior thyroid artery	-	1
Cricothyroid artery	-	1
Anterior jugular vein	1	3
Branch of inferior thyroid vein	-	3
Branch of thyroid vein	-	1
Branch of anterior jugular vein	-	1
Cartilage	***Partial***	***Complete***
Thyroid lamina	1	2
Cricoid	1	2
Trachea rings	2	-
Muscles	***Partial***	***Complete***
Sternothyroid	2	2
Cricothyroid	7	-
Sternohyoid	5	5
Thyroatenoid	1	-

Occasional bilateral or multiple injuries were noted in the same cadaver and were counted as separate injuries. Of note there were no significant vascular injuries and only one oesophageal injury, which occurred during the single tracheostomy.

The medical students placed the pen successfully in 3 of 4 (75%) attempts and the doctors were successful in 6 of 10 attempts (60%). Due to the small numbers no attempts at statistical comparison between the two were made.

LIMITATIONS

There are multiple limitations to any cadaveric, procedural model. Cadavers are very different from real patients in a pre-hospital setting. While cadavers provide a bloodless setting that might make the procedure easier, it must be noted that embalmed cadavers are usually in fixed positions and palpation and mobility of landmarks such as the thyroid and cricoid cartilages is greatly reduced, arguable making the procedure more difficult.

It is not possible to ventilate embalmed cadavers. As a result we were unable to assess whether any of the placements may have allowed ventilation or resulted in subcutaneous emphysema if ventilation had been attempted.

DISCUSSION

In the clinical scenario outlined to participants, we suggested an acute airway obstruction, likely from a food bolus that produced a 'can't intubate, can't oxygenate' situation. In such a scenario, any available emergency care providers would expect to find themselves asked to intervene. Such a situation would require improvisation in the absence of equipment, training or expertise.

While it is unlikely that most emergency care providers will find themselves in the clinical scenario outlined in our study, emergency cricothyroidotomy does have the potential restore oxygenation and avoid cardiac arrest.

This is the first study to assess the feasibility of emergency cricothyroidotomy with an improvised, non-medical device. We observed that just over half of our untrained, unprepared participants were able to place a cricothyroidotomy using only a ballpoint pen barrel and a blade. This would suggest that it is a feasible option in such a scenario.

The frequency of cartilage fractures, occurring in 4 of 14 (29%) procedures is somewhat concerning when compared with one previous cadaveric study where it occurred in 3 of 30 (10%) procedures. [9] However, the latter study was conducted on fresh frozen cadavers where the tissue flexibility is markedly different. It was also assessing a wire-guided technique versus a standard surgical technique using specifically designed medical equipment.

While not specifically recorded, the authors observed that most cartilage fractures occurred during placement of the pen barrel through the incision. There are likely two reasons for this. Firstly the height of the cricothyroid membrane is commonly reported as 9-10mm [10] and the external diameter of the pen used in our study was 8.9mm and was perhaps too large to fit through some of the membranes. Secondly, inexperience on the part of the participants meant that they may have had difficulty appreciating the appropriate angle to insert the barrel through the incision.

The study by Owens et al [8] did not specifically report the external diameters of the pens studied but our study suggests that an external diameter of almost 9 mm is at the upper limit of acceptable size.

Rates of successful cricothyroidotomy have been higher (65-100%) in prior cadaveric studies, [9, 11-15] though these were with specific airway equipment and the procedures were performed by physicians with at least some degree of training and experience. It is unknown how such training and experience would affect rates of success in our model.

CONCLUSION

In a cadaveric model, junior doctors and medical students were able to establish an emergency cricothyroidotomy just over half the time with only a ballpoint pen and a blade. It is unknown whether trained and experience providers would perform better.

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COMPETING INTERESTS

None declared.

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