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## Trends in Anaesthesia and Critical Care

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# Scalpel cricothyroidotomy: The importance of bougie coude tip and scalpel blade characteristics

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## ARTICLE INFO

### Article history:

Received 18 June 2021  
Received in revised form  
6 August 2021  
Accepted 10 August 2021

### Keywords:

Airway management  
Difficult airway  
Emergency front of neck access  
Scalpel cricothyroidotomy  
Cricothyroid membrane

## ABSTRACT

Scalpel cricothyroidotomy is a life-saving emergency procedure used for accessing the airway in a 'can't intubate, can't oxygenate' scenario. To date, various patient characteristics and imaging modalities have been investigated for improving emergency Front of Neck Access (eFONA) attempts. However, there is still a lack of consensus in determining the most effective bougie and scalpel to use. This study analysed six readily available bougies and three broad-based scalpels. We found significant heterogeneity between the coude tip angles and the depth of the bougies, as well as the cutting depth of the scalpels. Some of the bougies and scalpel blades currently available on the market may therefore be unsuitable for eFONA attempts in patients with a high body mass index (BMI) as the depth of the cricothyroid membrane is likely to be increased. We recommend anaesthetic departments, emergency departments and critical care units should review their current eFONA equipment to assess the suitability for use, particularly in patients with a raised BMI.

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## 1. Introduction

Scalpel cricothyroidotomy is a life-saving procedure to secure the airway in a 'can't intubate, can't oxygenate' (CICO) scenario [1,2]. Consensus on the best method to access the trachea for an emergency Front of Neck access (eFONA) does not exist. Conventional approaches utilise a variety of techniques (including surgical (scalpel) and percutaneous (cannula, seldinger) and are based on the current practices within an institution or country [2–5]. The 2015 Difficult Airway Society (DAS) guidelines within the United Kingdom (UK) for Plan D recommends a 'scalpel-bougie-tube' technique for an eFONA attempt [6]. This technique utilises a scalpel with a size 10 blade, a tracheal tube introducer (bougie) and a 6.0 cuffed tracheal tube. A transverse stab incision is made through the cricothyroid membrane (CTM) with the scalpel. The blade is then rotated by 90° with the sharp edge facing caudally, followed by insertion of the bougie through the opening alongside the scalpel blade. The final step involves railroading the tracheal tube over the bougie [6].

However, the performance of this time-critical procedure is

fraught with the potential for failure [7]. Reasons include technical inexperience and unfamiliarity with the procedure, difficult airway anatomy (especially in patients with deep neck structures), equipment issues [8,9] and non-technical skills/human factors [10–13]. There is also a dearth of evidence on the most suitable equipment specifications for scalpel cricothyroidotomy; especially the characteristics of the bougie, particularly when faced with deep neck scenarios [14]. A bougie with a short coude tip may not be able to reach the deeper CTM of a patient with a high body mass index [15]. Similarly, a stab incision made with a scalpel blade may be insufficient for reaching the airway lumen in some patients [16]. Unrecognised failure to reach the CTM during scalpel cricothyroidotomy can result in a false passage and potentially life-threatening sequelae [7].

This study aimed to assess the depth and angle of coude tips of various bougies, as well as compare the depth of different sized scalpel blades to highlight their suitability for scalpel cricothyroidotomy performance.

## 2. Methods

### 2.1. Bougie tip measurements

Six different bougies, all currently available on the market, were identified by searching the websites of several well-known airway

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### Abbreviations

BMI	Body mass index
CICO	Can't intubate, Can't oxygenate
CTM	Cricothyroid membrane
DAS	Difficult Airway Society
eFONA	emergency Front of Neck Access

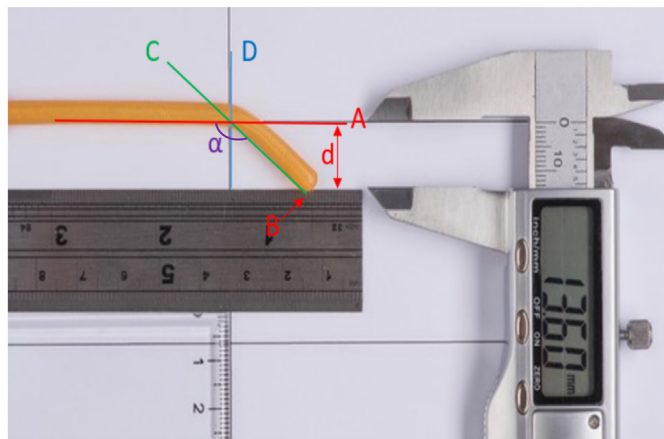
equipment suppliers. Bougies were used fresh from the packet, with care being taken not to alter their shape. We measured the coude tip depth and angle to define the characteristics of each bougie.

To measure the coude tip depth, each bougie was positioned so that the lower straight surface of the distal end of the bougie was resting on top of horizontal line A printed on a sheet of A3 paper (Fig. 1). This part of the bougie is the surface that would rest in contact with the neck during an eFONA attempt. We refer to this as its posterior surface concerning how it would be orientated relative to the patient during eFONA. A second line D was also printed on the paper, which ran vertically parallel and bisected line A at a right angle.

Each bougie was orientated so that the posterior surface of the body of the bougie was resting on top of line A. The bougie was then slid along line A so that the point at which the bougie begins to bend down into the coude tip was resting at the intersection with the vertical line D.

A fine pencil mark B was subsequently made at the most distal and lowest part of the bougie tip (tip of the red arrow B in Fig. 1). A metal ruler was then placed parallel to line A so that the long edge of the ruler is just touching the tip of the red arrow B. The linear distance between line A and the ruler's edge was measured as the coude tip depth ( $d$ ). This is the practical depth available to reach the airway lumen when the bougie is first inserted alongside the scalpel blade, as shown in Fig. 2A and Fig. 2B. This linear distance was measured using a pair of digital callipers (Reexbon 150 mm Digital Vernier Calipers, Northbrook tools®). Measurements were conducted independently by three investigators (CM, CP, KM), and the average of three measurements was recorded.

The second measurement was the coude tip angle. After



**Fig. 1.** Illustration of bougie coude tip measurements.

The  $\alpha$ -angle is the inner angle between lines A and C. The depth ( $d$ ) is measured as the linear distance between horizontal line A and the edge of the ruler. The intersection between line A and vertical line D represents the point where bougie tip starts to angle downwards. The point of the red arrow B represents the most distal and lowest part of the bougie tip. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

removal of the bougie from the paper, line C was then drawn from the pencil mark B to the intersection of Line A and the printed vertical line D. The inner angle between the between line A and line C (marked as the  $\alpha$ -angle in Fig. 1) was measured using a high-quality engineering protractor (15cm/180° rotation protractor, Mein HERZ®). As this could only be read to the nearest whole degree, it was measured only once for each bougie after consensus agreement was attained between three investigators (CM, CP, KM). This angle depicts the degree of downward bend of the coude tip.

Angles closer to 180° represent a shallower coude tip, while those closer to 90° represent a steeper coude tip.

### 2.2. Scalpel depth measurements

Three commonly used scalpel blades were chosen for the measurement of the depth (Fig. 3). This included a single-use size 10 blade (Swann-Morton, Sheffield, UK), a single-use size 22 blade (Swann-Morton, Sheffield, UK) and a size 20 blade (Swann-Morton, Sheffield, UK) attached to a reusable handle.

The distance of the distal end of the scalpel handle to the tip of the blade was measured for all three scalpel blades. As shown in Fig. 3, each scalpel handle with a blade was placed so that the distal end is aligned with the vertical line printed on a sheet of A4 paper. Measurements were conducted independently by three investigators (CP, KD, KM), and the average of three measurements was recorded in Table 2. This measurement represents the available length of the blade to reach the airway lumen. All measurements were recorded and analysed in Microsoft Excel®.

### 3. Results

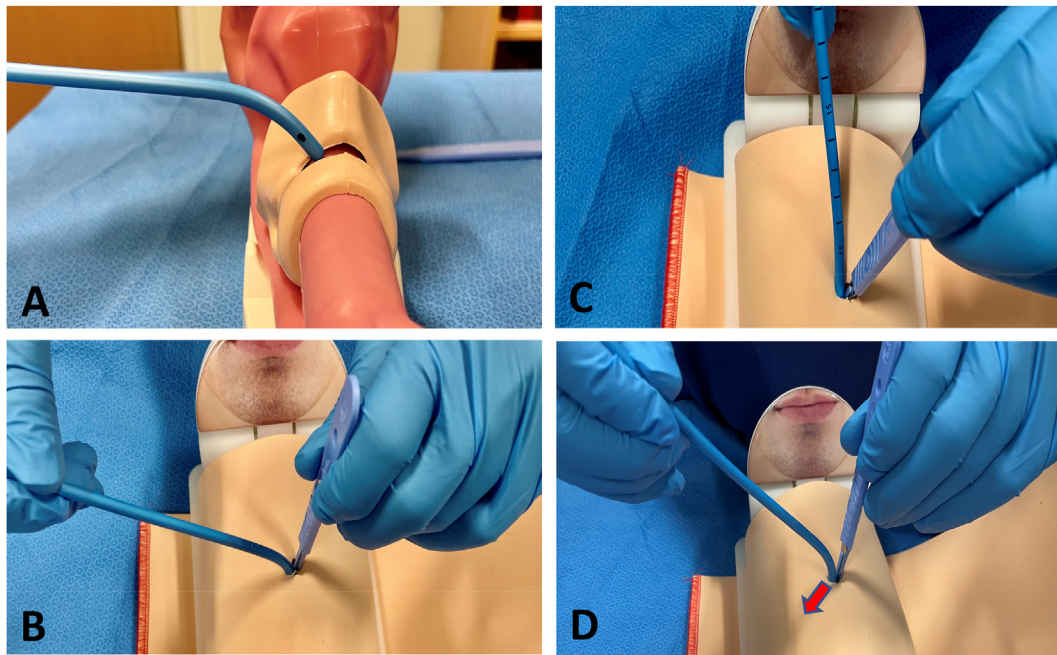
The bougie with the shortest coude depth was the Portex Single Use Bougie (Smiths Medical, Kent, UK) and had the shallowest angle at 161°. In comparison, the bougie with the greatest depth was the P3 tracheal tube introducer 15Ch (P3 Medical, Bristol, UK). The bougie with the most acute angle was the Venn reusable tracheal tube introducer (Smiths Medical, Kent, UK). These measurements are recorded in Table 1, and the characteristics can visually be appreciated in Fig. 4.

### 4. Discussion

Scalpel cricothyroidotomy is a time-critical and potentially life-saving procedure. Improvement in the technical aspects of this intervention is crucial to optimising patient care in the emergency setting of a CICO scenario. One of the main reasons DAS advocates the 'scalpel-bougie-tube' technique is because it offers a simple approach using immediately available and familiar equipment. Our study highlights the lack of standardisation of currently available bougies, specifically regarding the variety of coude tip characteristics between them.

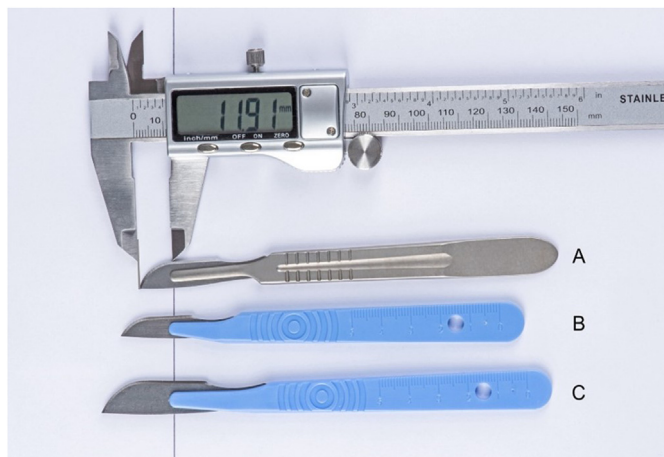
Currently, no distinction is made between bougies for aiding tracheal tube placement and those used for eFONA. There is increasing evidence that suggests a considerable heterogeneity of CTM characteristics within the general population. Several factors contribute to the depth of the CTM including gender, ethnicity, pregnancy and most importantly body mass index (BMI) [17,18]. Obesity has been shown to be associated with difficult face mask ventilation and laryngoscopy [19]. The incidence of difficult airway is higher in patients with an increased BMI, and increased depth of the CTM could further contribute to the complexity and failure of eFONA in these patients [1,15].

A positive correlation between BMI and CTM depth has been demonstrated using both computed tomography and ultrasound. For every 5 kg/m<sup>2</sup> increase in BMI, it is estimated that the CTM



**Fig. 2.** Steps for bougie insertion in scalpel cricothyroidotomy.

A. Holding the bougie parallel to the floor and right angle to the trachea. B. Sliding the coude tip of the bougie down the side of the scalpel blade. C. Aligning the bougie with the trachea and gently advancing into the trachea. D. Holding the bougie at a more vertical angle, to increase the available depth in situations where the CTM is deeply located. The red arrow denotes the bougie tip moving away from midline, which may potentially lead to formation of a false passage. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)



**Fig. 3.** Illustration of scalpel depth measurements.

A. Re-usable stainless steel 20 blade attached onto a stainless steel surgical scalpel handle. B. Disposable stainless steel 10 blade with polystyrene handle. C. Disposable stainless steel 22 blade with polystyrene handle.

depth increases by 2–3 mm [16], and in patients with a BMI over 40 kg/m<sup>2</sup> having a predicted depth of at least 16.8 mm [20]. In obstetric patients, it has been demonstrated using ultrasound that CTM depth is increased from 10.6 mm in non-obese women to 18 mm in those with a BMI over 45 kg/m<sup>2</sup> [15]. In addition, the thickness of the CTM can range from 2.9 mm in females to 4.5 mm in males [17]. These factors should be taken into consideration when choosing the depth of bougie and scalpel choice for eFONA.

Only half of the bougies assessed in our study had a coude tip depth greater than 11 mm. While these would likely be sufficient to reach the CTM in a non-obese patient, this may not be the case for those with an increased BMI. Significantly, none of the bougies in

this study would have been sufficient to reach a CTM depth of 18 mm. Therefore, an awake technique to secure the airway is generally considered a safer option in patients with an anticipated difficult airway, particularly where a greater CTM is predicted.

When performing scalpel cricothyroidotomy, the bougie should be held parallel to the floor and at the right angle to the trachea (Fig. 2A), with the coude tip slid down the side of the blade (Fig. 2B) [6]. In clinical situations where the CTM is located deeper than anticipated, the operator would be forced to hold the bougie at a more vertical angle to increase the achievable depth (Fig. 2D). This however may result in the coude tip not abutting the scalpel with the potential to create a false passage [14].

A more feasible solution may involve liaison with bougie manufacturers to produce a bougie designed specifically for scalpel cricothyroidotomy. Ideally, this would have a more elongated and steeper coude tip enabling a deeper-lying CTM to be reached, such as with obese patients. The most distal end of the tip should be soft, rounded, and atraumatic to avoid damage or potential puncture through the posterior tracheal wall.

We also assessed the cutting depth of the size 10 scalpel blade and compared it to two different sized broad-based scalpel blades. Size 10 was originally chosen for scalpel cricothyroidotomy as its wide curved edge can make a transverse incision that is large enough to accommodate a size 6.0 cuffed tracheal tube. However, its available depth of 16.6 mm suggests that it may not reach the airway lumen in all patients, especially those with a BMI above 40 kg/m<sup>2</sup>. A size 22 blade which has an available depth of 23 mm could instead be used for eFONA in obese patients. However, the advantage of its increased depth would need to be carefully balanced against the risk of increased trauma to the posterior tracheal wall and bleeding caused by a wider base of the blade.

There are several limitations to our study. Firstly, we only took measurements from six bougies currently available on the market and therefore the results of our research may not be representative



**Table 1**The coude tip  $\alpha$ -angle and depth of the six chosen bougies. Values are numbers and angles in degrees.

	Depth (mm)	$\alpha$ -angle °
1) Frova® Airway Intubation Catheter (William Cook Europe, Bjaeverskov, Denmark)	10.6	155
2) Portex® Single Use Bougie Coude Tip (Smiths Medical International Ltd, Hythe, Kent, UK)	8.6	161
3) Venn Reuseable Tracheal Tube Introducer 15 Ch x 600 mm (Smiths Medical International Ltd, Hythe, Kent, UK)	13.6	143
4) P3 Tracheal Tube Bougie 15 Ch x 800 mm (P3 Medical Ltd, Bristol, UK)	10.5	148
5) Intersurgical Tracheal Tube Introducer (Intersurgical, Wokingham, UK)	13.1	156
6) P3 Tracheal Tube Introducer Vented 15Ch x 800 mm (P3 Medical Ltd, Bristol, UK)	16.4	150

**Table 2**

The average depth of the cutting portion of the commonly used broad-based scalpel blades.

	Depth (mm)
1) Surgical scalpel blade size 20 (Swann Morton Ltd, Sheffield, UK)	11.9
2) Surgical scalpel blade size 10 (Swann Morton Ltd, Sheffield, UK)	16.6
3) Surgical scalpel blade size 22 (Swann Morton Ltd, Sheffield, UK)	23.1



1. Frova® Airway Intubation Catheter
2. Portex® Single Use Bougie (Coude Tip)
3. Venn Reusable Tracheal Tube Introducer – *most acute angle*
4. P3 Tracheal Tube Bougie
5. Intersurgical Tracheal Tube Introducer
6. P3 Tracheal Tube Introducer (Vented)

**Fig. 4.** Visual comparison between the six bougies.

of the entire selection of commercially available bougies. Secondly, measuring the depth of the coude tip requires the investigator to first identify the point at which the tip first begins to curve. This is somewhat subjective as not all bougies have a well-defined point at which the curvature begins. Hence, based on the distal angle of the bougie tip, there could be an inaccuracy of a few millimetres in the depth of the bougie measured. The use of an electronic calliper has a margin of error of 0.01 mm, although we tried to improve the reliability of the measurements by using a mean value derived from three individual readings. Additionally, it is also possible that some bougies based on their constructive material may flex during insertion, increasing the available depth of the bougie tip.

In situations where the CTM is deeply located and the anatomical landmarks are not palpable, a vertical skin incision and initial blunt dissection before stab incision may be required [6]. This may allow a standard blade length and coude tip to reach the airway lumen.

In addition to the scalpel blade depth, the scalpel blade's width is an essential consideration as it should ideally produce a stab

incision to accommodate a size 6.0 cuffed tracheal tube. The height of the CTM should also accommodate the width of the blade during the 90° rotation. The mean height of CTM can be < 8.0 mm in 9% of patients presenting for surgery [21]. As a result, further research on the width of blades is needed. Furthermore, reviewing bougies with newer tip designs would add value to our results in developing a purpose-made eFONA kit.

## 5. Conclusion

Our study demonstrates that the equipment recommended in Plan D for eFONA may require review regarding their specifications. In patients with larger neck circumference and deeply located CTM, both the scalpel and the coude tip of the bougie may be unable to reach the airway lumen. It is acknowledged that eFONA is a high pressure, high-risk situation, and in this regard it is vitally important that anaesthetists train in cricothyroidotomy. Repeated training in simulation, mannequins or cadaver models can lead to improved success in eFONA [4,5]. It is also important to understand

the decision-making process and not just the technical aspects involved in eFONA performance [4,5,22].

Recognition of the limitations of the current default equipment, potential modifications as suggested and encouraging anaesthetists to familiarise themselves with the equipment available in their institutions may improve the success rate when performing this procedure in an emergency.

### Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

### Author statements

Kavitkumar Dasari: This author helped with Data curation, Investigation, Formal analysis, Visualization, Writing, Review and editing. Kay Anne Mak: This author helped with Data curation, Investigation, Methodology, Visualization, Writing, Review and editing. Charles Pairaudeau: This author helped with Data curation, Investigation, Methodology, Formal analysis, Visualization, Review and editing. Cyprian Mendonca: This author helped with Conceptualization, Data curation, Investigation, Methodology, Visualization, Project administration, Supervision, Review and editing.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Acknowledgements

We would like to express our thanks to Dr Tim Davies and Dr Umair Ansari for their advice and suggestions to the study.

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