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Original Article

Impact of change in head and neck position on ultrasound localisation of the cricothyroid membrane: an observational study

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Summary

The ideal position for performing surgical cricothyroidotomy is with full neck extension. Some authors have recommended marking the cricothyroid membrane before general anaesthesia, typically with the patient's head and neck in a neutral position. The primary aim of this observational study was to determine whether skin marks made over the centre of the cricothyroid membrane with the head and neck in the neutral position moved outside the boundaries of the membrane when the neck was subsequently extended. The secondary aim was to assess changes in the height of the cricothyroid membrane between the neutral and extended positions. Twenty-two volunteers completed the study. With the head and neck in the neutral position, the distance between the upper and lower borders ('height') of the cricothyroid membrane was measured by a radiologist using ultrasound. The skin was marked over the mid-point of the membrane. The subject then maximally extended the neck, and the measurements and marking were repeated. The skin marking over the centre point of the cricothyroid membrane moved by median (IQR [range]) 5 (4–6 [0–10]) mm when the head and neck were moved from a neutral to a fully extended position. The initial skin mark moved to lie outside the boundary of the cricothyroid membrane in 12 of 22 subjects after extending the neck. The height of the cricothyroid membrane increased by 30% with the neck extended. We recommend that marking the skin in preparation for cricothyroidotomy should be performed with the neck extended, not with the head and neck in the neutral position as previously suggested.

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Introduction

Surgical cricothyroidotomy with a 6.0-mm tracheal tube is the recommended management in a 'can't intubate, can't oxygenate' emergency [1]. There are many technical and non-technical challenges to overcome in order to increase the chances of a positive outcome, but two issues have been raised recently in the anaesthetic literature which we believe to be misleading and/or incorrect.

Firstly, some authors have recommended marking the cricothyroid membrane (CTM) before induction of general anaesthesia if difficulty is anticipated [2, 3], thus avoiding the need to identify the membrane for the first time during an unfolding emergency. Although this seems to make sense, these authors have suggested marking the CTM in the neutral or intubating position. The optimal position for routine airway management [4] is different from that

recommended for surgical cricothyroidotomy, which is best performed with the patient's neck in full extension [1]. We hypothesised that when the neck is extended after marking the skin with the head and neck in the neutral position (as recommended in these studies), the initial mark may no longer overly the CTM, which may then result in increased risk of failure to secure a surgical airway in an emergency situation.

A second issue was raised in a study which suggested that a 6.0-mm tracheal tube may be too big to fit through the CTM [5]. Although this study provided the largest series of measurements to date, the height of the CTM was measured from scans of patients with the head and neck in a neutral position. We hypothesised that the height (distance between superior and inferior borders) of the CTM might increase with neck extension, making the value of measurements taken with the head and neck in a neutral position less relevant, also highlighting the importance of correct positioning for cricothyroidotomy.

Cadaver studies that examined location and movement of the cricothyroid membrane have been published [6–9] but a PubMed search using key words 'identification' and 'cricothyroid membrane' for the time period 1999–2017 did not identify any studies that assessed the location of the CTM with change in head and neck position in living people, nor any studies which indicated that change in position of head and neck had any effect on the height of the CTM. We were, therefore, unable to perform an a priori power analysis to determine an appropriate sample size to evaluate our two hypotheses using tests of statistical significance, so we designed an observational pilot study to help us decide whether our hypotheses were worthy of further investigation.

The primary aim of the study was to assess whether a skin mark made over the centre of the CTM with the head and neck in a neutral position moved outside the boundaries of the CTM when the neck was extended. The secondary aim was to determine if the distance between the upper and lower borders (height) of the CTM changed when the head and neck were repositioned from a neutral to an extended position.

Methods

This observational study was approved by Northampton General Hospital internal ethical committee and the North-West Greater Manchester South Health Research Authority.

Previous ultrasound studies of the CTM in cadavers [8, 9] used 23, 24 or 25 cadavers per group and showed good homogeneity within groups, so we planned to recruit 25 volunteers for our study.

After obtaining written informed consent, adult healthy volunteers were recruited from Northampton General Hospital staff. Exclusion criteria were arthritis, any restriction of neck movement, upper limb neurology and age less than 18 years. Baseline characteristics (sex, neck circumference, height and weight) were collected.

Each volunteer was positioned supine on an AneticAid Q3 (AneticAid, Basildon, UK) operating theatre trolley, with their head supported on a pillow to achieve a neutral position of the head and neck (plane of face parallel to the floor and external auditory meatus and sternal angle forming a straight line parallel with the floor). A consultant radiologist with more than 15 years' experience identified the upper and lower borders of the CTM using a GE Logic S8 linear multifrequency 6–18 MHz ultrasound probe (GE Healthcare, Cardiff, UK). The distance between the upper and lower borders (height) of the CTM was measured, and the mid-point of the CTM marked on the skin with a black surgical marker pen. The volunteer then maximally extended their neck and the same measurements were repeated. A new mark was made on the skin over the mid-point of the CTM with a red surgical marker pen, and the distance between the two skin mid-point marks was measured using a tape measure (Spentex Ltd, Leeds, UK).

Data for each subject were collected on a standard form identifiable only by participant number. Non-continuous data were analysed using the Wilcoxon signed-rank test. All statistical analyses were conducted utilising Sigmaplot 11.0 software (Systat, San Jose, CA, USA). A value of $p < 0.05$ was regarded as statistically significant.

Results

Thirty-one people enquired about the study. Seven decided not to take part having read the information sheet. Two people who agreed and signed the participant consent form withdrew from the study before taking part for logistical reasons (unable to attend during the study period), leaving 22 subjects who completed the study. There were 12 men and 10 women; mean (SD) height 1.69 (0.13) m, weight 73 (15) kg, BMI 25.5 (3.6) $kg.m^{-2}$, neck circumference 37 (4.3) cm.

The skin mark overlying the mid-point of the CTM moved by median (IQR [range]) 5 (4–6 [0–10]) mm when the head was moved from a neutral to a fully extended position, and in 12 of the 22 subjects the initial skin mark (made in the neutral position) lay outside the borders of the CTM following neck extension.

The height of the CTM increased by 30% with the change from neutral to maximal extension: median (IQR

Table 1 Height of the cricothyroid membrane (CTM) in neutral and extension and movement of the skin mark for each of the 22 study participants (all measurements in mm).

Height of CTM In neutral	Height of CTM In extension	Vertical movement of skin mark
7.0	10.0	10[a]
6.0	9.0	10[a]
7.3	9.5	4
7.9	10.4	6[a]
8.7	9.5	5[a]
8.6	10.0	6[a]
5.1	5.4	4[a]
6.4	10.0	5
6.6	10.0	10[a]
6.3	9.5	5[a]
7.1	10.2	3
4.6	6.0	6[a]
6.0	10.6	0
9.4	10.2	8[a]
6.1	9.0	5[a]
8.0	8.5	4
11.9	13.0	5
5.6	7.1	4[a]
7.4	9.3	4
9.0	10.0	4
6.8	11.0	5
6.8	9.1	2

[a]Initial skin mark lies outside the border of the cricothyroid membrane after extending the head and neck.

[range]) neutral 6.9 (6.2–8.0 [4.6–11.9]) mm, extended 9.8 (9.0–10.2 [5.4–13.0]); $p < 0.001$ (Table 1).

There was no correlation between cricothyroid membrane height and height, weight, BMI or neck circumference ($r = 0.19$, −0.2, −0.2 and 0.08, respectively).

A post-hoc power estimate for a paired comparison of two groups demonstrated a power of 0.999 with our sample size of 22 patients (difference in means = 2.2 mm; standard deviation of residuals = 1.96 mm; $\alpha = 0.05$).

Discussion

Contrary to published suggestions, this preliminary study demonstrates that a skin mark made over the mid-point of the CTM before induction of anaesthesia cannot be relied upon if the head and neck are subsequently extended to perform cricothyroidotomy. Our findings also show that the CTM consistently increases in height when the head and neck are extended, confirming the benefits of performing cricothyroidotomy in this position. Our results appear to be clinically relevant, with more than half of all skin marks moving outside of the CTM on extension and 18 out of 20 CTMs increasing in height on extension.

Volunteer trials utilising convenience sampling have a number of limitations, principally in terms of their generalisability to the population. It cannot be assumed that the volunteers in our study would be representative of a general surgical population, nor of a subset in whom airway management would be difficult. In convenience sampling, subjects are chosen due to their ready availability (in this study, anyone who worked at our hospital) with no inclusion criteria defined before selection. Although this methodology is vulnerable to selection bias and a high level of sampling error, it is recognised to be an appropriate option in order to obtain initial primary data regarding specific issues in areas that have not been studied previously (in this case, movement of a mark over the cricothyroid membrane).

Thirty years ago, limited head and neck extension was identified as a risk factor for patients who were difficult to intubate [10] and it is possible that this could affect the likelihood of a skin mark moving and also limit increase in height of the CTM. Other factors known to be associated with difficult airways may also have an effect on the variables we studied, and it would be possible to repeat our study in a subset of the surgical population with known difficult airways to determine if the effects we observed in our volunteers were replicated in this group of patients.

Our results demonstrate that in more than half of the sample studied a pre-operative mark made in the neutral position could not be relied upon after extending the neck. At the very least, this merits further study, and we would argue that while awaiting future studies it makes more sense to mark the centre of the cricothyroid membrane in the extended neck position in which a cricothyroidotomy would actually be performed.

A 6.0-mm internal diameter tube is recommended for emergency cricothyroidotomy [1]. A potential disadvantage of selecting a smaller tube is that it may not fit over a bougie, leading to technical failure half way through what could otherwise have been a successful airway rescue. We considered that the space between the cricoid cartilage and thyroid cartilage might open wider than the maximum height we measured once the cricothyroid membrane has been disrupted; this could be an area for cadaveric studies in the future. It should also be considered that tracheal tubes are not rigid cylinders; they are deformable, and so could potentially pass through spaces with an overall height less than their outside diameter. This would also be amenable to benchtop testing or cadaver studies.

Although there was no apparent correlation between height, weight, BMI or neck circumference and the height of the cricothyroid membrane in these volunteers, we cannot assume that this will necessarily be the case in a general surgical population, due to the limitations of convenience sampling discussed above.

There are many other factors which may contribute to the success (or failure) of emergency surgical cricothyroidotomy, such as: the degree of standardisation of equipment in an institution; the technical and non-technical skills of the staff on duty [11]; the availability and uptake of training; and the use of standard operating procedures and cognitive aids [12]. Some of these issues are amenable to prospective study, but unpicking the complexities of factors that contribute to the success or failure of emergency cricothyroidotomy is likely to depend on ongoing review of actual cases through a registry or similar process [13].

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