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# Can thickness of subcutaneous fat tissue limit emergency percutaneous cricothyrotomy?

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## ABSTRACT

**Introduction:** Needle cricothyrotomy is a method of maintaining airways in emergency situations. One of the identified factors that can make this procedure difficult to perform is 'a difficult neck anatomy' or a short obese neck. Due to the growing problem of obesity, we decided to estimate the feasibility of a needle cricothyrotomy by measuring the thickness of neck fat tissue in the population. Evaluation of this method is important because it is the only method that can be legally performed by paramedics in Poland. The aim of the study was to estimate the feasibility of needle cricoideotomy by evaluating the percentage of population in which the thickness of subcutaneous fat tissue could potentially limit or complicate such a procedure.

**Material and methods:** In this retrospective study we reviewed computed tomography (CT) scans of the neck from the database at the Department of Radiology, University Hospital in Cracow. 550 CT scans met inclusion criteria: age of patient over 18 years old, lack of any lesions altering the anatomy of measured region of neck, the first CT scan of patient. 50.36% of patients were women. The median age was 61 years (range 18–93). The distance from the skin surface at the level of the lower edge of the thyroid cartilage to the cricothyroid ligament (surface — ligament distance, SLD) was measured. Statistical analysis of the data was performed using R software (R version 4.0.3).

**Results:** Median SLD was 1.41 (1.01–2.04). Subcutaneous fat tissue was thicker than maximal depth of application of cricothyrotomy (3 cm) device in 31 patients (5.64%).

**Conclusions:** Performing needle cricothyrotomy may be limited to a considerable percentage of the population (5.64%).

**Key words:** Cricothyrotomy, difficult neck anatomy, emergency airway management, needle cricothyrotomy, obesity

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## Introduction

Percutaneous cricothyroidotomy is an emergency procedure that is used in a life-threatening airway obstruction to obtain ventilation and oxygenation when other, non-invasive techniques are ineffective or contraindicated. This situation is also known as a 'cannot intubate, cannot oxygenate' situation (CI-CO). Cricothyroidotomy may be performed by puncture (needle cricothyroidotomy) or surgical incision (surgical cricothyroidotomy) of the cricothyroid membrane [1].

Needle cricothyroidotomy is performed by puncturing the cricothyroid membrane with the needle and passing a catheter through it. This procedure is often performed with the use of a Quicktrach kit and provides temporary access to the airways. Surgical cricothyroidotomy requires a horizontal incision through the lower part of the cricothyroid membrane and passing a tracheostomy or endotracheal tube into the trachea. Surgical cricothyroidotomy provides more effective ventilation than needle cricothyroidotomy because of the larger diameter of the tube [2].

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It is important to distinguish these different techniques of emergency airway access because paramedics in the Emergency Medical Services in Poland are capable of performing only the needle cricothyroidotomy procedure. It is set out by the Regulation of the Minister of Health from 16 December 2019 [3].

Nowadays, the issue of obesity is very common. It can cause several obstacles during medical procedures including getting access to the obstructed airways [4]. Cricothyroidotomy as a technically difficult procedure is especially problematic in patients with a thick layer of neck fat tissue or a short neck. Additionally, the kits for cricothyroidotomy and the user manual do not include the limit values of the distance from the skin surface to the airways at which the procedure is possible to perform.

### Aim of the study

The aim of the study was to estimate the feasibility of needle cricothyroidotomy by evaluating the percentage of population in which the thickness of subcutaneous fat tissue could potentially limit or complicate such a procedure.

### Material and methods

We retrospectively reviewed radiological images from the database at the Department of Radiology, University Hospital in Cracow. We searched for computed tomography (CT) scans of the neck in a sagittal plane. We collected a database of CT scans of 600 patients from the period between 2015 and 2019.

The study protocol complied with the Declaration of Helsinki and was approved by the Bioethics Committee of Jagiellonian University in Cracow, Poland (No 1072.6120.194.2021.). The need for informed consent from all subjects was waived due to the nature of the study.

The inclusion criteria comprised patients aged over 18 years old that underwent CT scan of the neck. Only the first CT scan of a certain patient was used in case the patient had more than one CT scan during the given period. The exclusion criteria were as follows: age below 18 years old, second and further CT scans of the same patient, any lesions that altered anatomy of the measured region of the neck such as tumors, hematomas, abscesses, enlarged lymph nodes or thyroid glands. We excluded 50 patients. Causes of exclusion were enlarged thyroid glands (15 patients), abscesses or inflammatory changes (2 patients), neoplasm of larynx (10 patients), enlarged lymph nodes or hematological neoplasm located in the soft tissue of a neck (15 patients), hematoma located in soft tissues of a neck (1 patient), tracheostomy (7 patients).

We investigated CT scans of 550 patients, 277 (50.36%) of them were women. The median age was 61 (44–69) years with a range of 18–93.

Two measurements were made. The first measurement was the distance from the skin surface measured at the level of the lower edge of the thyroid cartilage to the cricothyroid ligament (SLD, surface–ligament distance). The second measurement was the diameter of the respiratory tract (DR) measured from the cricothyroid ligament to the posterior wall of the subglottic region of the larynx (Fig. 1). We also collected data such as age and gender of the patient.

We manually measured the maximal length of the application of the device (cannula and metal needle) by measuring the length of the applicable part of the device after removing the stopper. The maximal depth of application was 3 cm.

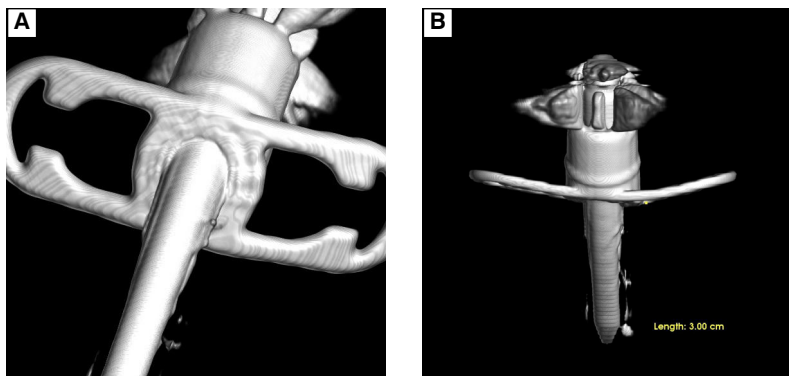
Based on the maximal length of application and performed measures we calculated the ratio between the difference of maximal length of application and SLD divided by DR (length of the device in airways to the diameter of respiratory tract ratio; DDR). This measure tells us how deep the device could be placed in the airways (Suppl. Fig.).

### Emergency percutaneous cricothyroidotomy equipment

There are two types of cricothyrotomy kits available on the market. Two sizes of sets are available depending on the patient's weight. One for pediatric patients



**Figure 1.** Computed tomography scan of neck used to assess surface–ligament distance (SLD) and diameter of the respiratory tract (DR)



**Figure 2.** 3D visualizations of cricothyrotomy device based on computed tomography scans; **A.** view from above; **B.** vertical view with maximal depth of application

(10–35 kg) and one for adults and older children (> 35 kg). The kit for adults consists of one syringe (with a cricothyrotomy needle, conical cannula, and safety stopper), one connecting tube with an adapter and one cushion neckband (Fig. 2). The measured maximum depth of application of the tracheal tube size 7 was 4.5 cm.

There are also kits for a classical surgical technique of cricothyrotomy. They contain a scalpel, a syringe, a cuffed tracheal tube with a dilator, neck tape, extension tubing, tracheal hook, blunt scissors, and speculum.

### Statistical analysis

Statistical analysis of the data was performed using R software (R version 4.0.3). Quantitative measurements were expressed as a median (IQR), and inner group comparisons were performed using the Mann-Whitney U test. Qualitative data were expressed as percentages, Fisher exact probability test was used for the data comparisons between groups. 95% CI intervals were computed using the exact method.

Mann-Whitney U test was used for comparisons between genders, parameters are shown as median (IQR). Pearson correlation coefficient was used to measure the correlation between age and measurements, absolute values less than 0.2 were treated as a lack of correlation.

Differences were considered statistically significant when  $p \leq 0.05$ . All reported p-values were two-sided and were not adjusted for multiple testing.

## Results

### SLD

Median SLD was 1.41 (1.01–2.04), mean SLD was  $1.58 \pm 0.79$ . The distribution of SLD is shown in Figure 3. In 31 patients (5.64%, 95 CI 3.86%–7.91%) SLD exceeded 3 cm. In 13 patients (2.36%, 95 CI 1.26%–4.01%) SLD

exceeded 3.5 cm. In 1 patient (0.19% 95 CI 0%–1.01%) SLD exceeded 4.5 cm. SLD was not significantly correlated with age or gender (Tab. 1).

### DR

Median DR was 2.04 (1.75–2.34), mean DR was  $2.1 \pm 0.5$ . Men had significantly larger DR (2.25 (2.03–2.49) vs. 1.82 (1.64–2.08);  $p < 0.001$ ). DR was not correlated with age (Tab. 1).

### DDR

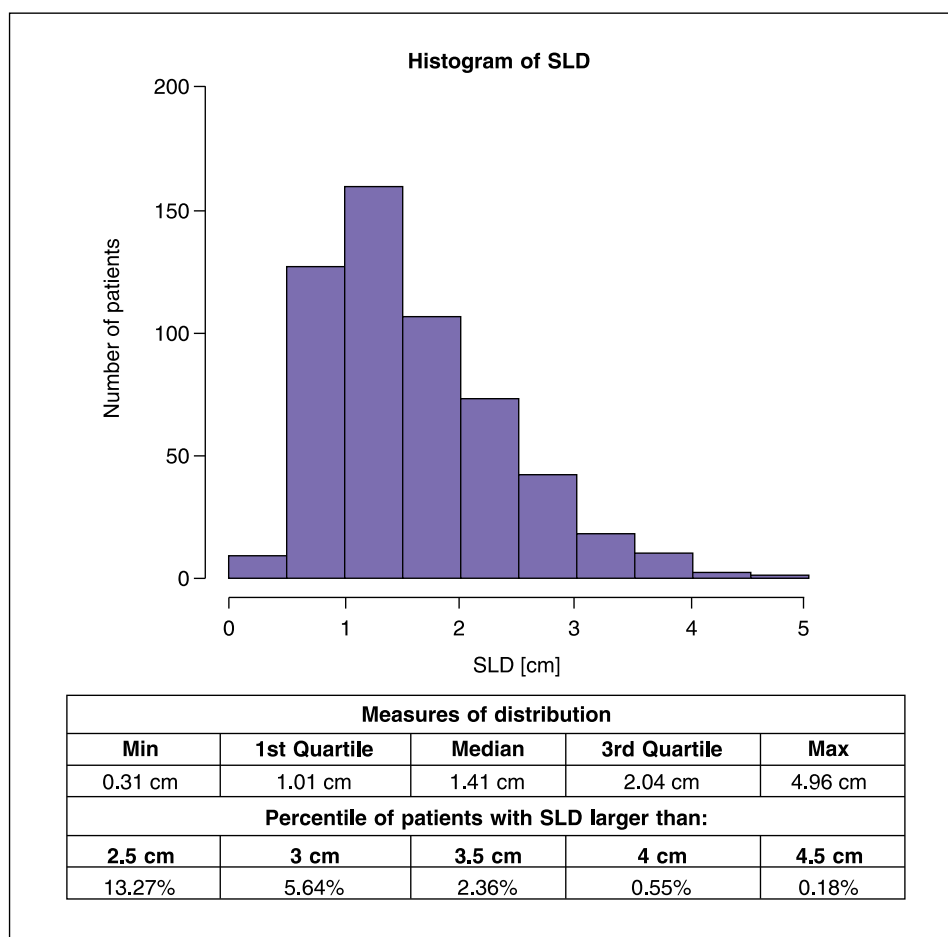
DDR was less than 50% in 158 patients (28.73%; 95 CI 24.98%–32.71%). DDR was less than 25% in 83 patients (15.09%; 95 CI 12.20%–18.36%). DDR was less than 10% in 45 patients (8.18%; CI 6.03%–10.79%).

## Discussion

Obesity is becoming more and more common. In 2015 107.7 million children and 603.7 million adults in 70 countries were obese [5]. Every overweight person and especially obese people are a challenge for medical equipment and personnel [6].

Lifesaving procedures need to be constantly improved and validated. The aim of our study was to estimate the feasibility of needle cricothyrotomy. We measured the percentile of patients with a thickness of layer of adipose tissue on the neck that could potentially be an obstacle in performing such a procedure.

Obesity is associated with a thicker layer of adipose tissue. The cricothyrotomy device may be too short and palpation of crucial anatomical structures may be implausible. However, every patient has an equal right to medical services based on the current state of medical science [7]. Medical workers and the medical industry are obliged to prepare adequate procedures and equipment for patients with different body sizes.



**Figure 3.** Histogram of surface–ligament distance (SLD)

**Table 1.** Associations between surface–ligament distance (SLD) and diameter of the respiratory tract (DR) and age and gender

	Gender		P-value	Age	
	Male	Female		Pearson correlation coefficient	P-value
SLD [cm]	1.39 (0.94–2.1)	1.43 (1.05–2.02)	0.2961	0.19	< 0.001
DR [cm]	2.25 (2.03–2.49)	1.82 (1.64–2.08)	< 0.001	0.08	0.0622

Our study shows that a considerable percentage of the population (5.64%) has a thick (> 3 cm) layer of neck fat tissue. The maximal length of application of the device used for needle cricoideotomy is 3 cm, thus performing needle cricothyrotomy is potentially limited or more difficult in that part of the population. In addition, 8.18% needle cricoideotomy devices would be relatively superficially placed (DDR < 10%) in the respiratory tract. We measured maximal depth of application of the device after removing the stopper, thus this depth is larger than the usual depth of inserting Quicktrach during puncturing the cricothyroid membrane. Gender and age were not associated with larger SLD.

After a thorough search through the PubMed database, we did not find any other study evaluating the distribution of thickness of neck fat tissue in patients populations.

Hossfeld et. al. carried out a study, in which on four anatomical neck variations (long slim/long obese/short slim/short obese) two surgical approaches to cricothyroidotomy were performed. The results showed that the time to access airways was longer in the short obese group than in the long slim group and the risk of unsuccessful procedures was increased in the short obese group compared to the long slim group. This study showed that difficulties in cricothyroidotomy may

arise from the anatomical factors such as the thickness of the skin of the patient's neck. [4]

Some previous studies showed that standard medical procedures may be inadequate for severely obese patients [8–10]. Obese people may need different equipment for needle decompression of a tension pneumothorax, due to larger chest wall thickness. At the time of that study (2013), the largest available needle (64 mm) for such a procedure was suitable for 79% of the patients. Positive correlation between BMI and chest wall thickness was proven. Previous study showed that a catheter of the length of 4.5 cm may be too short for a substantial amount (9.9–35.4%) of the population, depending on age and gender. The review of literature showed that an 8 cm needle would be suitable for 96–99% percent of patients [9]. Thus, we see a similar situation where equipment and procedures had to be adjusted in case of obesity.

Considerable (> 5%) and potentially growing percentage of the population in which needle cricothyrotomy is limited raises a question about available treatment options for them. For the reason explained below we believe that surgical cricothyrotomy would be adequate.

When similar problems arose with performing needle decompression of a tension pneumothorax enlarging size of the needle was sufficient resolution. In case of needle cricothyroidotomy this might not be the case. Larger size of needle is associated with a higher rate of complications [11] and size of needle might not be the only problem in performing this procedure in obese patients, another one might be palpating the landmarks.

The first step of performing cricothyrotomy is locating the cricothyroid membrane. Anatomical landmarks such as thyroid prominence and the gap between the lower thyroid cartilage and the cricoid ring can be usually located by palpation — performing “laryngeal handshake”. Thick fat layer can make these spots undetectable and performing cricothyrotomy would be more difficult.

Performing surgical cricothyrotomy is preferred over elective tracheostomy in obese patients due to difficult neck anatomy [12]. Open surgical access provides visibility of crucial anatomical structures [13]. Without that, locating the precise place of cannula insertion is often impossible due to large thickness of fat tissue or “lack of neck” [12].

Given the fact that half of performed needle cricothyroidotomy procedures are unsuccessful, search for additional methods is justified even if they make the procedure longer. Performing ultrasound to measure the distance from skin to airways before making cricothyrotomy in patients with difficult neck anatomy is also a potential field of investigation.

Based on literature and clinical experience, we recommend using surgical cricothyrotomy rather than needle cricothyrotomy in patients with a thick layer of neck fat tissue, and we suggest expanding the range of

legal therapeutic possibilities for prehospital personnel. Surgical method of cricothyrotomy was shown to be easier to learn for medical personnel naive to surgical airway techniques than needle cricothyrotomy [14].

### Study limitations

The actual percentage of people with high SLD in the overall population can be lower due to the possible selection of the study population.

Measurements used in our study are entirely theoretical and are based on the assumption that a layer of fat tissue of thickness larger than the maximal depth of application of an emergency cricothyrotomy device can limit the performance of emergency cricothyrotomy. Those measurements do not take into account biomechanical properties of the fat tissue.

There is also a possibility that distances measured in CT are larger because of the position of the head. The head bent back may cause flattening of the subcutaneous layer of the neck. However, bending the neck is not recommended in patients with neck trauma, thus our study may be more accurate for this type of situation.

### Conclusions

Our study supports the thesis that needle cricothyrotomy is limited to a significant percentage of the population (5.64%).

### Need for further studies

There is a need for several other studies: study correlating neck fat tissue with Body Mass Index (BMI); study measuring SLD in the population of emergency patients who needed cricothyrotomy to assess feasibility and rate of complication in patients with a thick layer of the neck fat tissue; functional study of changes of thickness of fat tissue on the neck depending on the position of head and study correlating thickness of fat tissue with the accessibility of anatomical landmarks.

**Ethics approval and consent to participate:** *The study protocol complied with the Declaration of Helsinki and was approved by the Bioethics Committee of Jagiellonian University in Cracow, Poland (No 1072.6120.194.2021.). The need for informed consent from all subjects was waived due to the nature of the study.*

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