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Comparison of Conventional Surgical versus *Seldinger Technique Emergency Cricothyrotomy Performed by Inexperienced Clinicians*

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Background: **Cricothyrotomy is the ultimate option for a patient with a life-threatening airway problem.**

Methods: **The authors compared the first-time performance of surgical (group 1) *versus* Seldinger technique (group 2) cricothyrotomy in cadavers. Intensive care unit physicians (n = 20) performed each procedure on two adult human cadavers. Methods were compared with regard to ease of use and anatomy of the neck of the cadaver. Times to location of the cricothyroid membrane, to tracheal puncture, and to the first ventilation were recorded. Each participant was allowed only one attempt per procedure. A pathologist dissected the neck of each patient and assessed correctness of position of the tube and any injury inflicted. Subjective assessment of technique and cadaver on a visual analog scale from 1 (easiest) to 5 (worst) was conducted by the performer.**

Results: **Age, height, and weight of the cadavers were not different. Subjective assessment of both methods (2.2 in group 1 *vs.* 2.4 in group 2) and anatomy of the cadavers (2.2 in group 1 *vs.* 2.4 in group 2) showed no statistically significant difference between both groups. Tracheal placement of the tube was achieved in 70% (n = 14) in group 1 *versus* 60% (n = 12) in group 2 (*P* value not significant). Five attempts in group 2 had to be aborted because of kinking of the guide wire. Time intervals (mean ± SD) were from start to location of the cricothyroid membrane 7 ± 9 s (group 1) *versus* 8 ± 7 s (group 2), to tracheal puncture 46 ± 37 s (group 1) *versus* 30 ± 28 s (group 2), and to first ventilation 102 ± 42 s (group 1) *versus* 100 ± 46 s (group 2) (*P* value not significant).**

Conclusions: **The two methods showed equally poor performance. (Key words: Airway; cricothyroid membrane; endotracheal intubation; trauma.)**

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THE final cannot-ventilate cannot-intubate option in all airway-management algorithms, whether they concern prehospital, emergency room, intensive care unit (ICU), or operating room (OR) patients, is insertion of a endotracheal tube *via* a cricothyrotomy.[1] There are currently two main methods of endotracheal tube insertion through a cricothyrotomy, namely the conventional surgical and blind Seldinger techniques. Unfortunately, because the procedure happens rarely, many caregivers (*e.g.*, nonsurgeon intensivists, anesthesiologists) have little experience with either method in real cannot-ventilate cannot-intubate situations in life-threatened patients. Consequently, it would be extremely important to know the fastest and most reliable method in the hands of first-time performers. The purpose of this study was to compare efficacy (speed and success rate) of standard surgical *versus* Seldinger technique cricothyrotomy performed by first-time inexperienced ICU physicians using both methods in cadavers.

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Materials and Methods

The study was approved by the Institutional Ethics Committee of the University of Vienna.

Study Design

We compared two methods of cricothyrotomy in adult human cadavers:

Group 1 (n = 20): Standard surgical cricothyrotomy using a no. 11 scalpel blade, a retractor, a tracheal dilator (Carl Reiner, Vienna, Austria), and a cuffed tracheal cannula with internal diameter 5.0 mm (Mallinckrodt, Argyle, NY).

Group 2 (n = 20): Seldinger technique for percutaneous dilational cricothyrotomy using a kit (Arndt Emergency Cricothyrotomy Catheter Set, Cook Critical Care, Bloomington, IN).

In a 60-min training session, the physician participants were first shown, using slides, the anatomic details of the region of interest, the American Society of Anesthesiologists and European Resuscitation Council Difficult Airway Algorithms,[2,3] and the tools of both methods (30 min). The component parts of both methods were then shown for 15 min each. Explanations were given according to instructions found in the literature[4,5] (group 1) and the instruction manual of the Seldinger kit (group 2). Afterward, there was time for questions and discussion. No video was shown of the procedure.

Group 1. After identification of the anatomic landmarks, the larynx was held in place by holding the upper pole of the thyroid cartilage firmly with the thumb and middle finger of one hand. The cricothyroid membrane (CTM) was then palpated with the index finger. A 3.0- to 4.0-cm midline vertical skin incision was made in the cadavers, cutting skin, fat, and muscle layers. Some physicians used the retractor or their fingers to keep the incision open. Then a 1.5- to 2.0-cm transverse incision was made at the inferior third of the CTM. The resulting hole was enlarged with the dilator, and the cuffed tracheal cannula was inserted. After inflation of the cuff and the first ventilation from a breathing bag, placement was confirmed by using the esophageal detection method with either an aspiration syringe (Ambu TubeChek Syringe, Ambu, Linthicum, MD) or the self-inflating bulb (Ambu TubeChek-B, Ambu). This evaluation completed the procedure from the viewpoint of the participant.

Group 2. After location of the CTM, the trachea was punctured with an 18- gauge thin wall needle, and air was aspirated into a syringe filled with water. The 0.035-in guide wire in the kit was inserted *via* the needle into the trachea. The needle was removed over the wire, the puncture site enlarged by a stab with a no. 15 scalpel blade (leading to a vertical incision about 4 mm in length), and the uncuffed tube with the dilator inserted into the trachea over the wire. The dilator and the wire were removed from the tube, ventilations were performed, and placement was evaluated as in group 1.

Each attempt was watched by one of us (P.E., K.L.), and the participants were put under stress by constantly reminding them that only 2 min were allowed, because 1 min had already passed trying or considering another method. The participants were allowed only one attempt per procedure and cadaver.

Participants

The participants were ICU physicians (residents and fellows) who had been trained in critical care medicine for 1 to 5 yr. Each participant had performed numerous conventional endotracheal intubations with the aid of a laryngoscope or fiberscope, but no participant had performed a previous cricothyrotomy, with either the surgical or Seldinger technique. All participants had had at least some minimal training ($>$ 3 months) in surgery, making them familiar with a scalpel, but not in neck surgery.

Cadavers

The study was performed in 40 consecutive unembalmed adult human cadavers who had died 4–24 h before the procedure. Participants had no influence on the choice of cadavers. The order of the two methods was randomized. Tracheal tubes *in situ* were removed before the procedure. The cadaver was lying flat on the dissecting table with a roll under the neck or the shoulder. Inclusion criteria consisted of adult male and female human cadavers ($>$ 19 yr of age) in the morgue. Exclusion criteria consisted of previous neck surgery or disease.

Evaluated Parameters

Age, sex, height, weight, and neck circumference of the corpses were recorded. We measured three time intervals, using a stopwatch: from the start of the procedure to location of the CTM, tracheal puncture or penetration with scalpel, and the first ventilation with a breathing bag. Subjective assessment of the difficulty of the anatomic situation (obesity, short neck, bullneck) and the ease of use of each method was given by the participants on a visual analogue scale from 1 (easiest) to

Table 1. Surgical *versus* Seldinger Technique Cricothyrotomy (N = 40)

	Surgical (n = 20)	Seldinger (n = 20)
Age (yr)	63 ± 10.5	62 ± 14
Males/females	13/7	11/9
Height (cm)	170 ± 10	167 ± 8
Weight (kg)	76 ± 18	74 ± 15
Distance thyroid cartilage—chin (cm)	7.8 ± 1.6	7.5 ± 2.1
Neck circumference (cm)	41.6 ± 5.8	40.7 ± 5.1
Distance cricothyroid membrane—suprasternal notch (cm)	6.0 ± 1.7	5.5 ± 1.0

Values are mean ± SD.

5 (worst). The pathologist dissected the neck and examined the position of the cannula, assessing the correctness of placement in the trachea and any potential injury inflicted.

Statistics

For statistical analysis, the Student *t* test was used. Statistical calculations were performed with the help of the software package SAS (version 5.0; Statistical Analysis System, Cary, NC). $P < 0.05$ was considered statistically significant. Results are reported as mean values ± SD.

Results

Age, height, weight, and neck circumference of the cadavers were not significantly different between the two groups (table 1). The measured time intervals are listed in table 2. No significant differences could be found with respect to the three time intervals recorded. Subjective assessments of the ease of the methods and the anatomic situation were equal between groups (table 2).

Tracheal placement of the cannula was achieved in 70% (n = 14) in group 1, and in 60% (n = 12) in group 2. This difference was not statistically significant. Failures in group 1 resulted from paratracheal (n = 1), esophageal (n = 1), or subcutaneous (n = 2) misplacement of the cannula. One failure resulted from unsuccessful attempts to locate the CTM, another from abortion of the procedure based on assumption of esophageal position although the tube was in correct tracheal position. Failures in group 2 resulted from kinking of the guide wire in five cases and anterior (n = 1), lateral (n = 1), or esophageal (n = 1) misplacement. In the cases of guide-wire kinking, the soft, flexible tip of the wire got entangled in the T joint of the kit, or the "check-flow" valve. The correct or incorrect placement of the needle had no influence on the entanglement.

The gender distribution among the failures was two males and four females in group 1 and five males and three females in group 2 (*P* value not significant).

Incidence of injuries was equal between groups (15% in group 1, 10% in group 2, *P* not significant). Most injuries were esophageal perforations (n = 2) and punctures of the thyroid vessels (n = 3).

Discussion

Difficulty in establishing a secure airway is not a rare event. In the American Society of Anesthesiologist's Closed Claims Study, 34% of the claims were related to airway management.[6] The correct sequence of procedures to be performed if confronted with airway-management difficulties has been standardized,[2,3] and training in the performance of its components is of considerable priority for anyone working in emergency room, ICU, or operating room facilities.

We found that cricothyrotomy could be successfully established by ICU physicians performing the procedures for the first time in about two thirds of cadavers using both methods. Failures using the surgical method resulted mainly from misplacements; technical problems were encountered using the Seldinger technique. Although the red plastic sheath has to be held in a retracted position during the air-aspiration maneuver, the sheath has to be pushed forward for introduction of the guide wire. If the sheath is not pushed forward, the guide wire kinks during insertion and may not be used for another insertion attempt. This problem was responsible for five aborted attempts in group 2 (out of eight failures). We therefore recommend special emphasis on this aspect in teaching the Seldinger kit.

Lack of experience has been acknowledged as the main source of cricothyrotomy failure,[4,7] because practice op-

Table 2. Surgical *versus* Seldinger Technique Cricothyrotomy (N = 40)

	Surgical	Seldinger
Time to location of membrane (s)	7 ± 9	8 ± 7
Tracheal puncture (s)	46 ± 37	30 ± 28
First artificial ventilation (s)	102 ± 42	100 ± 46
Subjective assessment cadaver (1–5)	2.2	2.4
Kit (1–5)	2.2	2.4

portunities of any kind are scarce. This was the reason why each participant was allowed only one attempt in this study, to simulate the real world and avoid a study-induced learning curve. As an additional observation, we noticed that many of the physicians performed far better with continued practice. Therefore, the rescuer should use the method he or she is most accustomed to.

It has to be stated that cadavers do not reflect the real-life situation. Lung edema in cadavers might influence the aspiration of air with the Seldinger kit, leading to false negative assessment of the position the needle. Surgical incision in the living patient undergoing cricothyrotomy may lead to surgical bleeding, thereby impairing visualization of the anatomic structures. In living trauma patients, difficulty in performing cricothyrotomy may also be caused by coagulopathy, hypertension, and subcutaneous distortion.[8] In particular, in the case of maxillofacial, mandibular, or neck injury preventing oro- or nasotracheal intubation, there may be concomitant trauma of the trachea, making orientation difficult for surgical access of the CTM.

Surgical cricothyrotomy has been proven to be equally feasible for surgeons, anesthesiologists, and intensive care specialists.[9] Because our participants were ICU physicians who had used the Seldinger technique for other procedures and also had some surgical training, we do not think our participants were biased toward one method or the other. Our time intervals differed from previous studies, in which surgical[10,11] and percutaneous[12] access required less time for paramedic students, medical students, or interns (46 ± 17, 43 ± 44, and < 30 s, respectively). Our incidence of injury was less than in a study in dogs[13] but comparable to a complication rate of 14% in patients.[12]

In conclusion, first-time performers of both surgical and Seldinger technique cricothyrotomy have similarly poor results in cadavers. Further studies are needed to define the learning curve for both surgical and Seldinger technique cricothyrotomy.

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