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Evaluation of Seldinger Technique Emergency Cricothyroidotomy versus *Standard Surgical Cricothyroidotomy in 200 Cadavers*

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Background: **Percutaneous cricothyroidotomy is a lifesaving procedure for airway obstruction in trauma victims who need airway establishment and cannot be intubated or in whom intubation has failed.**

Methods: **The purpose of this study was to examine whether there is a training effect using Seldinger technique emergency cricothyroidotomy (group 1; Arndt Emergency Cricothyroidotomy Catheter Set; Cook Critical Care, Bloomington, IN) *versus* standard surgical cricothyroidotomy (group 2). Twenty emergency physicians performed five cricothyroidotomies with each method in a total of 200 human cadavers, comparing efficacy and safety (speed, success rate, and injuries).**

Results: **Seven attempts in group 1 and six in group 2 had to be aborted. Time intervals from the start of the procedure to location of the cricothyroid membrane were not significantly different between the groups. However, time to tracheal puncture ($P < 0.01$) and time to first ventilation ($P < 0.001$) were significantly longer in group 2. No time effect could be observed in both groups. The airway was accurately placed into the trachea through the cricothyroid membrane in 88.2% (82 of 93) of the cadavers in group 1 and in 84.0% (79 of 94) in group 2 (not significant). No injuries were observed in group 1, whereas there were six punctures of the thyroid vessels in group 2 ($P < 0.05$).**

Conclusions: **With respect to time needed for the procedure, the participants performed Seldinger technique emergency cricothyroidotomy significantly faster as compared with standard surgical cricothyroidotomy. Even if no training effect had been observed, the authors believe that it is important to train residents in different methods of cricothyroidotomy in cadavers in addition to training in mannequins to achieve a higher level of efficacy in real-life situations. The shorter time to first ventilation and the fact that no injuries could be observed favor the Seldinger technique.**

THE cannot-ventilate, cannot-intubate situation necessitates a lifesaving cricothyroidotomy when all other non-invasive methods, such as Combitube™ (Tyco Healthcare, Mallinckrodt, Pleasanton, CA), *Laryngeal Mask Airway™* (Laryngeal Mask Corp., Henley-on-Thames, United Kingdom), and transtracheal jet ventilation, have failed. Cricothyroidotomy may be necessary in a life-threatening prehospital difficult airway situation, in an unexpected difficult airway in the emergency department, in the intensive care unit, or in the operating room. However, emergency cricothyroidotomy is performed infrequently even by emergency physicians and therefore can be difficult to perform in a real-life situation. In a previous study, we compared two methods of cricothyroidotomy (conventional surgical and Seldinger techniques) with respect to efficacy. We observed that performance was equally poor with both methods, and training would likely be necessary to improve skills.[1] The aim of the current study was to investigate these two methods with respect to the training effect of gaining experience. The training effect was evaluated by observing 10 randomized procedures performed by each participant using the two techniques in human cadavers.

This article is featured in "This Month in Anesthesiology." Please see this issue of ANESTHESIOLOGY, page 5A.

Materials and Methods

The Institutional Ethics Committee of the University of Vienna (Vienna, Austria) approved this study.

Study Design

Twenty emergency physicians of the Viennese Ambulance Services (Vienna, Austria) were recruited to participate in this study. During a period of 14 months, we compared two methods of cricothyroidotomy in 200 adult human cadavers within 24 h after death. The components of both sets were shown and explained to the participants.

Group 1 (n = 100 Cadavers). The Seldinger technique kit for percutaneous dilational cricothyroidotomy (Arndt Emergency Cricothyroidotomy Catheter Set; Cook Critical Care, Bloomington, IN) consists of a number of items, including a straight introducer needle (18 gauge), a syringe, a guide wire (diameter, 0.038 in = 0.97 mm; Amplatz extra-stiff wire guide (Cook Critical Care)), a dilator, a precurved uncuffed catheter (ID, 3 mm; length, 6.0 cm) with a Luer-Lok connector for transtracheal ventilation, and connecting tubing with a

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15-mm connector. The Seldinger technique consisted of the following steps:

1. identification of neck structures, followed by a vertical stab incision of the skin overlying the cricothyroid membrane (CTM) with use of a No. 11 rounded-blade scalpel;
2. insertion of an 18-gauge hollow needle attached to a 6-ml syringe through the skin incision and underlying CTM into the trachea in a caudal direction;
3. confirmation of needle placement into the trachea by aspirating air into the syringe, which was filled with saline;
4. if confirmed, removal of the syringe from the needle and, after advancing the red plastic sheath into the valve, insertion of a guide wire through the needle into the trachea, after which the needle was removed, leaving the wire in place;
5. with the guide wire in place in the trachea, insertion of an uncuffed precurved catheter and connecting tubing with a 15-mm connector over the wire into the trachea; and
6. removal of the dilator and guide wire, leaving the airway in place in the trachea.

Group 2 (n = 100 Cadavers). The standard surgical cricothyroidotomy technique consisted of the following steps:

1. identification and immobilization of neck structures, followed by vertical skin incision with use of a No. 11 rounded-blade scalpel;
2. transverse incision of the CTM with the same No. 11 blade scalpel;
3. insertion of a tracheal hook with cephalad retraction;
4. insertion of a Viennese tracheal dilator model (Carl Reiner, Vienna, Austria);
5. placement of a cuffed tracheal cannula (ID, 5.0 mm; Mallinckrodt, Argyle, NY); and
6. removal of the hook, dilator, and tracheostomy tube stylet.

Emergency physicians (n = 20) each performed both procedures on five different adult human cadavers after a 30-min training session. During this training session, a lecture was given—without audiovisual aids—about the two different techniques with regard to handling, and an explanation of anatomical landmarks in cadavers was provided. The question was whether training is necessary for adequate performance and for improvement in duration of the procedure after five attempts with each technique. Ease of use, anatomical situation of the neck, and time intervals from the start of the procedure to location of the CTM, as well as to tracheal puncture and to the first ventilation by rebreathing bag, were recorded. Each participant was allowed as many attempts per day on different cadavers as there were human cadavers available. An independent pathologist inspected cadavers for accuracy of placement and complications.

Cadavers

The study was performed in 200 refrigerated, non–formalin-fixed adult human cadavers who had died within 4–24 h before the procedure. Participants had no influence on the choice of the cadavers. The cadavers were used consecutively. The physicians were assigned randomly by procedural technique. Tracheal tubes *in situ* were removed before the procedure.

Participants

Twenty emergency physicians of the Viennese Ambulance Services participated in the study. Only one of them had previously performed one standard surgical cricothyroidotomy; the other 19 participants had no previous training or experience in performing cricothyroidotomies. They had to perform each technique five times within a time period of 4 months for each individual participant. The order of the several attempts with each technique was randomized and not consecutive, and the physicians were allowed only one attempt per procedure and cadaver. We made appointments with the participants in advance, not knowing whether there would be a cadaver in which to perform a cricothyroidotomy that day.

Evaluated Parameters

Age, sex, height, weight, body mass index, distance between the chin and the sternal notch, and neck circumference of the cadavers were recorded. We recorded three time intervals, using a stopwatch, from the start of the procedure to (1) location of the CTM, (2) tracheal puncture and insertion of the cricothyroidotomy tube, and (3) first ventilation with a breathing bag. After each procedure, an anatomical dissection was performed by a pathologist, who examined proper placement of the airway through the CTM and into the trachea. During the dissection, structures also were inspected for any complications, including damage, such as lacerations or fractures to the trachea, cricoid, or thyroid cartilages. In addition, punctures of thyroid vessels were recorded.

Statistical Analysis

Statistical analysis of the data was performed using the Wilcoxon test for comparing the two groups and two-way analysis of variance for differences among the five trials within the respective groups. Results are reported as mean ± SD.

Results

Results in 13 cadavers could not be evaluated because of incomplete data, not because of any complication or

Table 1. Patient Characteristics and Training Times

Variable	Group 1 Seldinger Technique, Mean ± SD (Range)	Group 2 Surgical Technique, Mean ± SD (Range)
Age, yr	64.0 ± 13.8 (24–87)	66.6 ± 15.7 (26–147)
Height, cm	170.4 ± 9.2 (146–190)	169.8 ± 10.7 (144–196)
Weight, kg	76.7 ± 20.0 (39–170)	83.8 ± 23.4* (36–150)
Body mass index, kg/m^2	26.4 ± 5.9 (12.9–47.0)	28.8 ± 6.3 (16.0–50.2)
Neck circumference, cm	38.8 ± 5.9 (25–70)	40.4 ± 5.7† (29–71)
Distance from chin to jugulum, cm	13.5 ± 2.1 (9.0–18.0)	13.7 ± 1.9 (9.0–18.0)
Time until location of CTM	7.9 ± 11.0 (2.0–80.0)	8.2 ± 9.7 (2.0–65.0)
Tracheal puncture and insertion, s	98.7 ± 58.3 (40.0–490.0)	119.2 ± 61.2‡ (30.0–335.0)
First ventilation, s	108.6 ± 59.5 (45.0–495.0)	136.6 ± 66.3§ (35.0–360.0)

* $P < 0.02$. † $P < 0.05$. ‡ $P < 0.01$. § $P < 0.001$.
CTM = cricothyroid membrane.

inability to proceed with the tube (7 in group 1, 6 in group 2).

Age, sex, height, body mass index, and distance between the chin and the sternal notch were not significantly different between the two groups (table 1). The weight of the cadavers ($P < 0.02$) and the circumference of the neck ($P < 0.05$) were significantly higher in group 2. Seven attempts had to be aborted because of the inability to advance the tube into the trachea due to kinking of the wire of the Seldinger kit in group 1, whereas six attempts had to be aborted in group 2 due to anatomical reasons or impossibility of inserting the cannula. Time intervals (mean ± SD) from the start of the procedure to location of the CTM were not significantly different between the groups. However, times to tracheal puncture ($P < 0.01$) as well as time to first ventilation ($P < 0.001$) were significantly longer in group 2.

No time effect could be observed in both groups (table 1). Graphs showing the time to successful ventilation for each participant at each try are presented in figs. 1A and B. The times for the first try *versus* the fifth try with each method are provided in table 2.

The airway was accurately placed into the trachea through the CTM in 88.2% (82 of 93) of the cadavers in group 1 and in 84.0% (79 of 94) in group 2 (not significant). In group 1, we found four subcutaneous misplacements of the cannula but no paratracheal or esophageal misplacements ($P > 0.05$). There were no paratracheal, esophageal, or subcutaneous misplacements of the cannula in group 2.

No injuries were observed in group 1, whereas there were six punctures of the thyroid vessels in group 2 ($P < 0.05$). No esophageal perforation was observed.

Discussion

Results suggest that training showed no significant beneficial effect.[2–6] The time to first ventilation was significantly shorter (mean difference, 28.0 s) with the Seldinger technique in cadavers. One could argue that the higher weight (mean difference, 7.1 kg) and neck circumference (mean difference, 1.6 cm) might be responsible for the difference of time needed between the groups. However, the differences in weight and circumference of the neck were not clinically relevant. Furthermore, there were no injuries observed with the Seldinger technique. Therefore, the results tend to be in favor of the Seldinger technique as compared with the standard surgical method. Further, the majority of the physicians in our study preferred the Seldinger technique to the standard cricothyroidotomy because of smaller skin incision avoiding major bleeding.

Although difficulty in establishing a secure airway in the field is not rare, emergency cricothyroidotomy is performed infrequently. In a recent article, Vadodaria *et al.*[6] compared four sets designed for emergency cricothyroidotomy: the Quicktrach (VBM Medizintechnik GmbH, Sulz am Neckar, Germany), the Patil airway set, the Transtracheal Airway Catheter, and the Melker set (the last three sets all from Cook Critical Care). The authors found that the preassembled Quicktrach set provided the fastest and most effective means of oxygenation in simulated patients that required an emergency surgical airway. However, using a patient simulator does not reflect the situation of a human cadaver. Therefore, the results may be misleading.

Standard surgical cricothyroidotomy has long been recognized as the definitive means of obtaining airway access in critically ill patients in whom conventional methods of airway control have failed or are contraindicated. A number of alternative cricothyroidotomy techniques have been developed, often in prepackaged commercially available kits, such as the Pertrach (Engineered Medical Systems, Inc., Indianapolis, IN) and the NuTrake (Emergency Medical Products, Inc., Waukesha, WI).[7] Abbrecht *et al.*[8] reported that ease of use and risk of complications such as posterior tracheal injuries with certain devices was related to insertion force and device characteristics including diameter and curvature. We have not found any injury to the posterior tracheal wall. An important finding in the study of Abbrecht *et al.* was that the use of small pilot needles to guide insertion of large cannulas minimized complications.

Eisenburger *et al.*[1] reported that the Seldinger technique had a similar complication rate compared with standard surgical cricothyroidotomy when performed one time in human cadaver models. Emergency cricothyroidotomy must often be performed under life-threatening situations in which airway access cannot be obtained by conventional means. Lack of experience and

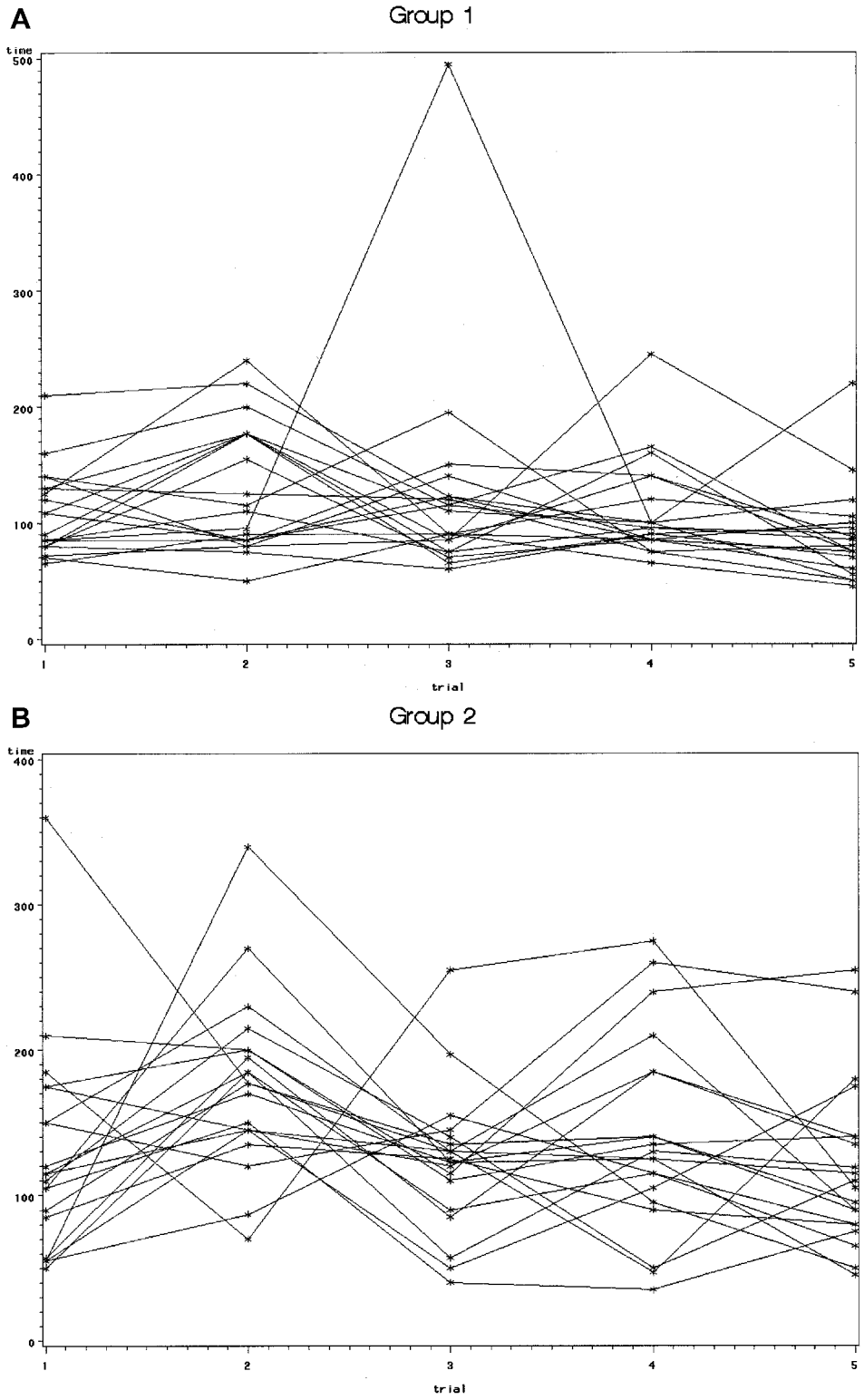

Fig. 1. Time to successful ventilation for each participant on each try using the Seldinger method in group 1 (*A*) and surgical method in group 2 (*B*).

practice has been acknowledged as the main source of failure.[9] Failures using the Seldinger technique were mainly due to misplacement, whereas the surgical method led to injuries of the thyroid vessels. Technical problems were encountered using the Seldinger technique: The red plastic cannula must be held in a retracted position during the air aspiration maneuver, whereas it must be pushed forward for introduction of

Table 2. Time (in Seconds) of the First *versus* the Fifth Try for Each Participant on Each Try

	Group 1 Seldinger Technique		Group 2 Surgical Technique	
Participant	First Try	Fifth Try	First Try	Fifth Try
1	85	90	110	110
2	80	75	55	115
3	140	50	120	45
4	120	85	185	105
5	72	145	115	NA
6	130	80	150	90
7	80	95	210	255
8	130	70	175	140
9	140	100	360	90
10	125	100	150	240
11	70	45	50	65
12	210	NA	105	95
13	85	220	115	135
14	NA	55	175	175
15	90	75	55	80
16	85	60	57	140
17	160	75	105	75
18	80	50	55	50
19	65	105	90	180
20	NA	87	85	80

NA = data not available.

the guide wire. When the cannula is not pushed forward, the guide wire kinks during insertion and may not be used for another insertion attempt.[1] This problem was responsible for seven aborted attempts in the Seldinger technique group (out of seven failures) in our study.

A correctly performed cricothyroidotomy may be lifesaving in a cannot-ventilate, cannot-intubate situation. However, many practicing anesthesiologists do not have experience with cricothyroidotomy.[10] The purpose of a recent study was to determine the minimum training required to perform cricothyroidotomy in 40 s or less in mannequins.[11] There was a significant reduction of cricothyroidotomy times over the 10 attempts ($P < 0.0001$) and between 3 consecutive attempts until the fourth attempt ($P < 0.03$). The cricothyroidotomy times plateaued by the fourth attempt, whereas the success rate plateaued at the fifth attempt (94, 96, 96, and 96% at the fourth, fifth, sixth, and seventh attempts, respectively). The authors suggested that practice in mannequins leads to reductions in cricothyroidotomy times and improvement in success rates. By the fifth attempt, 96% of participants were able to perform the cricothyroidotomy successfully in 40 s or less. Although clinical correlates are not known, the authors recommended that providers of emergency airway management be trained on mannequins for at least five attempts or until their cricothyroidotomy time is 40 s or less.[11]

A possible limitation of our study is that it does not reflect the real-life situation. Lung edema in cadavers might influence the aspiration of air during use of the Seldinger kit, leading to false-negative assessment of the position. The smaller skin incision made with the Seldinger technique may be advantageous because it leads to less bleeding. However, cricothyroidotomy in cadaver models does not reflect all aspects of common cricothyroidotomy complications, such as bleeding, infection, subglottic stenosis, and injury to vessels or nerves.[5,12] Although several methods, such as the Combitube™ and the *Laryngeal Mask Airway™*, may be used in the cannot-ventilate, cannot-intubate situation, cricothyroidotomy is the method of choice when tracheal intubation and alternate methods fail.[13,14]

We believe that it is important to instruct residents in different methods of cricothyroidotomy in cadavers, mannequins, or both to achieve a higher level of efficacy in real-life situations. The shorter time to first ventilation and the fact that no injuries were observed favor the Seldinger technique.

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