Surgical approach in difficult airway management

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In all difficult airway algorithms, cricothyroidotomy is the life-saving procedure and is the final ‘cannot ventilate, cannot intubate’ option, whether in pre-hospital, emergency department, intensive care unit, or operating room patients. Cricothyroidotomy is a relatively safe and rapid means of securing an emergency airway. As with all other critical procedures in emergency medicine, a thorough knowledge of the technique and adequate practice prior to attempting to perform an emergency cricothyroidotomy are essential.

Key words: difficult airway management; surgical airway; cricothyroidotomy.

The American Society of Anesthesiologists (ASA) task force on management of the difficult airway defined a difficult airway as the clinical situation in which a conventionally trained anaesthesiologist experiences difficulty with either mask ventilation or tracheal intubation, or both.1 Within this context, numerous recommendations and algorithms for managing these critical situations have been published.2-4 In all of these difficult airway algorithms, cricothyroidotomy is the life-saving procedure, and is the final ‘cannot ventilate, cannot intubate’ option, whether in pre-hospital (Figure 1), emergency department, intensive care unit, or operating room patients.

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Cricothyroidotomy involves establishment of an opening into the airway at the level of the cricothyroid membrane. It is readily accepted as a means of obtaining emergency access, but unfortunately has been the focus of significant controversy since the publication of Jackson’s landmark article in 1921. The controversy surrounding the procedure generally focuses on a particular complication: subglottic stenosis. In the late 1970s and early 1980s Brantigan and Grow, and Greisz et al, reported their results with elective cricothyroidotomy. As a result of these reports there was a renewed interest in the procedure on both an elective and an emergent basis. The approach to emergency cricothyroidotomy is somewhat different from that advocated for the elective procedure. Elective cricothyroidotomy involves the placement of a tube through the cricothyroid membrane incision under elective conditions, usually in the operating room or intensive care unit. Emergency cricothyroidotomy is performed in the emergency department or even in the field; it necessarily has a higher complication rate than does elective cricothyroidotomy but is also essentially a life-or-death procedure. Accordingly, a higher complication rate is acceptable considering the risk of fatality associated with failure to secure the airway. It is therefore, essential to remember that, although a serious debate concerning the merits of cricothyroidotomy rages in the literature, this debate has little application to the emergency procedure.

**Practice points**

- airway is always the first priority
- cricothyroidotomy is a good means of emergency access for a wide variety of providers
**INDICATIONS**

Cricothyroidotomy is indicated for emergency airway control when bag-mask-valve ventilation and endotracheal intubation attempts have failed and adequate oxygenation of the patient is not possible. Therefore, cricothyroidotomy is a life-saving procedure which is the final ‘cannot-ventilate, cannot-intubate’ option in all airway algorithms.

According to the guidelines of various international societies—such as the ASA, the International Liaison Committee on Resuscitation (ILCOR), the American Heart Association (AHA) and the European Resuscitation Council (ERC)—the laryngeal mask and the Combitube™, and the laryngeal tube, all supraglottic (non-surgical) airway devices, are acceptable alternatives prior to a cricothyroidotomy. In patients in whom an obstruction of the upper airway makes an airway access by conventional endotracheal intubation or by a supraglottic airway device impossible (e.g. in cases of severe burns to head, face and neck, severe maxillofacial trauma, inhalation trauma), cricothyroidotomy has to be performed immediately.

However, there are some not-so-standard indications that have been proposed for cricothyroidotomy, especially in the pre-hospital setting; e.g. when endotracheal intubation attempts have failed, or adequate oxygenation by bag-mask-valve ventilation or a supraglottic airway device seems to be possible but not acceptable for further (pre-hospital) management. An example of such a situation is a patient with severe maxillofacial injury in whom pre-hospital endotracheal intubation has failed, but oxygenation is possible by bag-mask-valve ventilation or by a supraglottic airway device; due to a long transport time to the trauma centre and to further massive neck swelling, a secondary loss of airway access is probable, and so a cricothyroidotomy is performed at this early stage. This indication is not as strong as the first-mentioned, and there are a number of considerations—e.g. alternatives for airway access, whatever method the provider has most experience with, the risk of aspiration, the length of the transport time, the possibility of intervention during transport—which influence the decision whether to perform a cricothyroidotomy in the individual case or not.

**INCIDENCE**

In the literature, emergency cricothyroidotomy is described as an ‘infrequent’ or ‘uncommon procedure of which the exact frequency is not known’. The incidence of emergency cricothyroidotomy seems to vary considerably depending on a number of
factors: e.g. the setting in which this procedure is performed as well as the personnel performing it. An American study on the experience with cricothyroidotomy in the pre- as well as the in-hospital setting has shown that the frequency of emergency cricothyroidotomy in the pre-hospital setting was much higher (10.9%) than that of in-hospital cricothyroidotomy in the emergency department (1.1%), although 90% of all intubations have been performed in the emergency room and only 10% in the pre-hospital setting. In a study on pre-hospital cricothyroidotomy by paramedics, a frequency of 14% was reported, whereas in studies on pre-hospital cricothyroidotomy by physicians frequencies between 0.1 and 3.3% were reported.

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<td>- the frequency of pre-hospital emergency cricothyroidotomy seems to be higher than that in the in-hospital setting</td>
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ANATOMY

Cricothyroidotomy involves simply making an opening in the cricothyroid membrane. This laryngeal membrane is trapezoidal and extends from the inferior border of the thyroid cartilage to the superior border of the cricoid cartilage. It averages approximately 9 mm in its superior–inferior dimension and 30 mm in its left–right dimension. The structures overlying the cricothyroid membrane include only skin, subcutaneous tissue, thin fascial layers, and the small-calibre cricothyroid ramus of the superior thyroid artery, which runs transversely across the upper third of the membrane. The vocal cords are generally located at least a centimetre above the cricothyroid space and are therefore protected during the normal performance of an emergency cricothyroidotomy. In general, the airway can be located by first identifying the laryngeal prominence (Adam’s apple); the cricothyroid membrane can usually be found approximately 1–1.5 fingerbreadths below the laryngeal prominence in the midline of the neck. Below the membrane, the cricoid cartilage should be easily palpated. Important anatomical structures, which are very close to where the membrane is entered, are the thyroid gland with its vessels and the large vessels of the neck (common carotid artery, internal and external jugular veins) as well as the oesophagus behind the trachea (Figure 2).

TECHNIQUES

A number of different techniques for performing cricothyroidotomy has been described in the literature. According to Mutzbauer et al., all these techniques can in principle be assigned to two groups: anatomical–surgical and puncture (Table 1). Independently of the technique used to perform an emergency cricothyroidotomy, there are some demands on the equipment used for cricothyroidotomy:
The cricothyroidotomy tray should be simple; only a few instruments are required for successful completion of this procedure, and cluttering the tray with unnecessary additional instruments will only lead to confusion and failure when the provider is attempting to perform the procedure rapidly in a life-threatening situation. As an example of such a basic cricothyroidotomy tray, a cricothyroidotomy set for an anatomical-surgical technique is shown in Figure 3.

- The equipment must be immediately available (any time, any place).
- These instruments must be ready to use as well as easy to use.
- The cricothyroidotomy tube must have an integrated standard connector for artificial ventilation.
- The risk of injuring anatomical structures in the vicinity of the cricothyroid region must be low.

In principle, and independently of the technique used, the identification of the ‘landmarks’ for cricothyroidotomy, as well as the performance of cricothyroidotomy itself, is made much easier with the head hyperextended on the neck. On the other hand, experience with cadavers showed that there was no difficulty in performing the procedure and no delay in cricothyroidotomy time caused by limited head mobility.

### Table 1. Techniques for performing cricothyroidotomy.

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<td>Puncture techniques:</td>
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<td>1. Stylet technique</td>
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<td>(a) Ravussin jet-ventilation catheter</td>
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<td>(b) Cricothyroidotomy cannula with large diameter (e.g. Quicktrach™ 4 mm²⁵ Portex Crico kit™ 6 mm)</td>
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<td>(c) temporarily with large-diameter intravenous cannula.</td>
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<td>2. Seldinger technique; there are a number of commercial kits available (e.g. Melker cricothyroidotomy set with cuffed tube)²⁶²⁷</td>
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extension. In the literature, the cervical spine injury is noted as an indication for cricothyroidotomy; within this context, Gerling et al, in their study on the effect of surgical cricothyroidotomy on the unstable cervical spine, have shown that the movements caused by the procedure itself—and therefore the danger of aggravating the situation by cricothyroidotomy—is from the clinical point of view not relevant.

As examples, detailed descriptions of an anatomical–surgical preparation technique, a puncture–stylet technique and puncture–Seldinger technique will follow.

**Anatomical–surgical preparation techniques**

**Conventional preparation technique**

- **Prepare the neck.** If possible, the patient should be supine, with the head hyper-extended on the neck by placement of e.g. a rolled sheet beneath the shoulders (cave: cervical spine injury). In emergency situations, a very rapid application of disinfectant will be allowed at that time.
- **Identify the landmarks.** Generally, the right-handed operator stands on the patient’s right side. This allows the left hand to immobilize the larynx and assist in landmark identification (laryngeal prominence and cricothyroid membrane) while the right hand performs the procedure.
- **Immobilize the larynx.** This is a very important step in performing cricothyroidotomy. Walls observed that inexperienced people who fail at cricothyroidotomy often do so because they do not keep the larynx absolutely secure and hence lose the landmarks during the procedure. In the right-handed model, the thumb and long fingers of the left hand are used to grasp the upper poles of the thyroid cartilage, allowing the index finger of the left hand to rest on the membrane. Once the larynx

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**Figure 3.** Cricothyroidotomy set used at HEMS Christoph 22/Ulm, Germany. It consists of: (1) scalpel No 11; (2) single-use Metzenbaum scissors; (3) Kilian speculum; (4) Mallinckrodt Safety-Flex tube, internal diameter 6.5 mm (armed tube with low-presssure cuff); (5) atraumatic suture 2-0; (6) transparent sterile drape; (7) surgical suction.
is immobilized in that fashion, the index finger of the left hand can be used gently to palpate once again the anterior surface of the thyroid cartilage, the cricothyroid space, and the cricoid cartilage. Even in cases of significant bleeding, a re-identification of the cricothyroid membrane will always be possible.

- **Incise the skin.** The incision of the skin (recommended: No. 11 scalpel blade) must be vertical and midline; it should be approximately 2–3 cm in length from the depth of the thyroid cartilage, membrane, and cricoid cartilage. The vertical incision will minimize initial vascular disruption (Figure 4).

- **Prepare subcutaneous tissue.** Blunt preparation of subcutaneous tissue is carried out with preparation scissors (e.g. Metzenbaum scissors) down to the cricothyroid membrane.

- **Incise the membrane.** The membrane should be incised transversely using the same No. 11 scalpel blade. The transverse incision should be in the midline and at least 1.5 cm long to facilitate tube placement. Withdraw the scalpel and use the Kilian speculum to demonstrate the incision of the cricothyroid membrane (Figure 5).

- **Place tracheal tube.** A 5.0–6.5-mm armed cuffed endotracheal tube is passed through the incision (Figures 6 and 7). This procedure must be done gently and with care, while the Kilian speculum is removed slightly to make space for the tube. Overly vigorous attempts to place the tube may result in a via falsa or in damage to the cuff. The cuff is inflated and the patient ventilated. Correct tube placement is confirmed using currently accepted techniques such as auscultation and/or capnography.

- **Secure the tube.** The tube is secured with tube ties or with sutures.

### Rapid four-step technique

The rapid four-step-technique is a modification of this anatomical-surgical technique. The operator stands (or kneels) above the patient's head and incises the skin and the cricothyroid membrane transversely. A special tracheal hook is inserted through the incision; the cricoid cartilage is then taken with the tracheal hook and moved to a more ventral and caudal position. The endotracheal tube is then inserted under the hook through this opening into the trachea.
Puncture techniques

**Stylet technique**

As an example of a stylet technique the instructions for use of the Portex Crico kit (Figure 8) are described.

- **Prepare the neck.** If possible, the patient should be supine, with the head hyper-extended on the neck by placement of e.g. a rolled sheet beneath the shoulders (cave: cervical spine injury). In emergency situations, a very rapid application of disinfectant will be allowed at that time.
- **Identify the landmarks.** The operator stands behind the patient's head. In the right-handed operator, the left hand is used to immobilize the larynx and assist in

![Figure 5. Transverse incision of the cricothyroid membrane with scalpel No. 11.](image)

![Figure 6. Prior to insertion of the cuffed tracheal tube with assistance of the Kilian speculum after incision of the membrane. The insertion has to be done gently; during insertion, the tracheal tube has to be turned 180° and pushed caudally.](image)
landmark identification (laryngeal prominence and cricothyroid membrane) while the right hand performs the procedure.

- **Immobilize the larynx.**
- **Incise the skin.** A 2-cm incision is made through the skin only over the cricothyroid membrane. An adequate incision length is vital to ensure that the tube will pass through the skin easily.
- **Puncture the skin.** The device is held with the thumb on the needle hub and forefingers under the tube flange. With the trachea stabilized, the needle tip is placed centrally over the cricothyroid membrane perpendicular to the skin.
- **Insert the device.** The device is inserted with constant observation of the red indicator flag in the needle hub. The red indicator flag confirms contact of the blunt stylet/needle with tissue (Figure 9a). The device is advanced until a loss of resistance is felt and the red indicator flag in the needle hub disappears, confirming entry into the trachea (Figure 9b). A confirmatory air aspiration test may be conducted if desired using the syringe provided. The device should continue to be carefully inserted until the red flag is observed to move again in the needle hub, confirming contact of the blunt stylet with the posterior cricoid cartilage (Figure 9c).
- **Place the tube.** The device is angled in a caudal direction and advanced 1–2 cm into the trachea. The needle is removed, and whilst the dilator is held stationary, the cricothyroidotomy tube is slid off the dilator fully into the trachea. The dilator is completely removed from the tube, and the cuff is inflated (Figure 10). Correct tube placement is confirmed using currently accepted techniques such as auscultation and/or capnography.
- **Secure the tube.** The tube is secured with either the tube holder or sutures provided.

*Figure 7.* Insertion of the tracheal tube (cuffed tube). During insertion, the Kilian speculum has to be removed slightly to make space for the tube.
Seldinger technique

To illustrate the Seldinger technique, the instructions for use of the Melker cricothyroidotomy set (Figure 11) with cuffed tube are described.

- **Prepare the neck.** If possible, the patient should be supine, with the head hyper-extended on the neck by placement of e.g. a rolled sheet beneath the shoulders (cave: cervical spine injury). In emergency situations, a very rapid application of disinfectant will be allowed at that time.
- **Identify the landmarks.** The operator stands behind the patient’s head. In the right-handed operator, the left hand is used to immobilize the larynx and assist in landmark identification (laryngeal prominence and cricothyroid membrane) while the right hand performs the procedure.

**Figure 8.** Commercial cricothyroidotomy kit: Portex Crico kit™. The 6-mm cuffed tube includes an integral needle/obturator/dilator assembly for rapid percutaneous placement. The needle incorporates a spring-loaded safety stylet to indicate the location of the needle tip during the procedure and to provide visual confirmation of its entry into the trachea.
Immobilize the larynx.

Puncture the skin and the cricothyroid membrane. The skin and the cricothyroid membrane are punctured with the puncture cannula with connected syringe. Aspiration of air confirms entry into the trachea.

Insert the wire guide. The syringe is disconnected from the needle. The wire guide is inserted through the needle (Figure 12), and the needle is then removed. The skin on each side of the wire guide is incised for 0.5–1 cm.

Insert the dilator and airway catheter. The curved dilator together with the connected deflated airway catheter is pushed gently over the wire guide through the skin into the trachea (Figure 13). The dilator is removed, the cuff inflated, and correct tube placement confirmed.

Secure the tube. The tube is secured with either the tube holder or sutures provided.

**Figure 9.** (a) Placement of the device over the cricothyroid membrane; insertion of the device, with constant observation of the red flag indicator in the needle hub. The red flag confirms contact of the blunt stylet/needle with tissue. (b) The device is advanced until a loss of resistance is felt and the red indicator flag in the needle hub disappears, confirming entry into the trachea. (c) The device is then advanced until the red flag is observed to move again in the needle hub, confirming contact with the posterior cricoid cartilage.
Cricothyroidotomy is the life-saving procedure in the final ‘cannot ventilate, cannot intubate’ option. Furthermore, emergency cricothyroidotomy is described as an ‘infrequent’ or ‘uncommon procedure of which the exact frequency is not known’. Therefore, the technique (as well as the equipment) used to perform an emergency cricothyroidotomy has to be simple as well as fast and safe. There are some criteria, which allow a more or less objective comparison of the different cricothyroidotomy techniques. According to Mutzbauer et al., these criteria are:

- Time needed to complete the procedure and to oxygenate the patient;
- Quality of ventilation;
- Protection against aspiration;
- Complication rate.

**Comparison of different cricothyroidotomy techniques**

Time needed to oxygenate the patient

Data in the literature on this topic are scarce. In a study on their experience with cricothyroidotomy, Bair et al., have shown that in 26% of the patients in whom an emergency cricothyroidotomy was performed (surgical–anatomical/rapid four-step technique) the procedure took more than 2 minutes. In a very small case study, Breitmeier et al., have shown that an experienced provider can perform an emergency cricothyroidotomy within 30 seconds (anatomical–surgical technique). Mutzbauer et al., in their study in unfixed cadavers reported a time to complete the procedure.
(conventional surgical technique) of 73 seconds for experienced but 180 seconds for inexperienced residents in anaesthesiology. In a study on the comparison of conventional surgical versus Seldinger technique in unfixed cadavers by inexperienced clinicians, Eisenburger et al.\textsuperscript{27}, demonstrated that there were no significant differences in primary success rate, the time to complete the procedure, and the complication rate between these two techniques; furthermore, the authors described a clear learning curve in performing the different techniques by the primarily inexperienced providers. Their conclusion from their study was to ‘do what you can do best’, i.e. surgeons should use the conventional surgical technique, while anaesthesiologists and intensive care specialists should use the Seldinger technique.\textsuperscript{27}

**Practice points**

- the time to complete an emergency cricothyroidotomy seems to depend on the (surgical) training and experience of the provider; the more experienced the provider is, the faster the procedure is performed
- ‘do what you can do best’—i.e. choose the technique you are used to performing in daily routine (e.g. surgeons, surgical technique; anaesthesiologists, Seldinger technique)

**Quality of ventilation**

There are few data available in the literature on this topic. There is one recent study on the ventilation of a model lung using various cricothyroidotomy devices.\textsuperscript{31} In this model,
a minute volume of up to 15 L/min over a cuffed endotracheal tube (internal diameter 6 mm) was possible, whereas the maximum minute volume in the non-cuffed cricothyroidotomy tubes (internal diameters 4 and 6 mm) was only 5 L/min. Adequate ventilation over a 13-G canula was not possible (maximum minute volume 2 L/min). The technique used for ventilation, however, was not comparable to a rescue ventilation procedure by use of a bag-valve device. Oxygenation, however, might be adequate by use of any of these techniques.

**Practice points**

- the larger the ID of the tracheal tube used for cricothyroidotomy, the higher the quality of ventilation
- the quality of cuffed endotracheal tubes is higher, compared to that in non-cuffed tubes of the same size (ID)
- there is no adequate ventilation, when a 13-G-canula is used for cricothyroidotomy

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**Figure 12.** Puncture of the skin and the cricothyroid membrane with the puncture cannula with connected syringe. Aspiration of air confirms entry into the trachea. The syringe is disconnected from the needle. The wire guide is inserted through the needle.
Protection against aspiration

In the assessment of protection against aspiration with various cricothyroidotomy devices, it is essential whether the tube has an inflatable cuff or not. In this context, it is important to note that various new cricothyroidotomy kits with an inflatable cuff (e.g. Melker cricothyroidotomy set, Portex Crico kit) are now on the market.

Complication rate

Most studies of complication rates have been on elective procedures. Nevertheless, this provides important background for the emergency procedure because many of the complications could be anticipated to be identical in both circumstances. Previous studies have indicated complication rates for cricothyroidotomy up to approximately

Practice points

- adequate protection against aspiration is possible only with cuffed tubes

Figure 13. The needle is removed. The skin is incised for 0.5–1 cm on each side of the wire guide. The curved dilator together with the connected deflated airway catheter are pushed gently over the wire guide through the skin into the trachea. The dilator is removed, the cuff inflated, and correct tube placement confirmed.
40% when performed under emergency conditions.\textsuperscript{10,16,31–34} Acute complications include the potentially life-threatening failure to establish an airway and bleeding. Long-term complications include subglottic stenosis, infections, and dysphonia.\textsuperscript{19} Mutzbauer et al\textsuperscript{29}, found predominantly venous bleeding, injury to the cartilages and tube dislocation as complications in a surgical technique on unfixed cadavers. Bair et al\textsuperscript{21}, in 50 successfully performed emergency cricothyroidotomies performed with a conventional surgical technique and the rapid four-step technique, found predominantly tube placement problems (mainly pre-tracheal tube placements), the necessity for a direct revision of the incision, and the necessity for replacement of the tube. Massive bleeding as well as problems in inserting the tube may occur in patients with a struma.\textsuperscript{29}

The kind of complications of cricothyroidotomy may be technique-related. In a comparison between a conventional surgical technique and the rapid four-step technique, the time needed to place the tube was shorter with the rapid four-step technique, but the complication rate was higher than in the conventional surgical technique.\textsuperscript{35,36} Based on the results of their study, Toye and Weinstein\textsuperscript{37} suggested that cricothyroidotomy via the Seldinger technique damaged the tissues less than a surgical technique. In general, puncture techniques may have a lower rate of bleeding complications than conventional surgical techniques because of less damage to the tissues.\textsuperscript{26,27}

### CONCLUSION

In all ‘difficult airway algorithms’ cricothyroidotomy is the life-saving procedure and is the final ‘cannot ventilate, cannot intubate’ option. Emergency cricothyroidotomy is indicated when bag-mask-valve ventilation and endotracheal intubation attempts have failed and adequate oxygenation is not possible. The principle problem with performing emergency cricothyroidotomy is not the procedure itself but the decision by the surgically inexperienced provider to perform it in a life-threatening situation. Emergency cricothyroidotomy seems to be an infrequent and uncommon procedure, although the exact frequency is unknown. It involves simply making an opening in the cricothyroid membrane. The techniques for performing cricothyroidotomy can be classified as anatomical, surgical or puncture techniques. The equipment used for cricothyroidotomy should be simple and available immediately (any time, any place); the instruments must be ready for use, and the (cuffed) tube must have a standard connector for artificial ventilation. Furthermore, the risk of injuring anatomical structures must be low. The time needed to complete an emergency cricothyroidotomy seems to depend not only the technique used but also on the surgical training and experience of the provider: the more experienced the provider is, the faster the
procedure is performed. Within this context it is recommended to ‘do what you can do best’ (e.g. surgeons should use the surgical technique, anaesthesiologists the Seldinger technique). Large-diameter cuffed tubes ensure adequate ventilation and protect effectively against aspiration. Acute complications include the potentially life-threatening failure to establish an airway and bleeding. As with all other procedures in emergency medicine, a thorough knowledge of the technique and adequate practice prior to attempting to perform an emergency cricothyroidotomy are essential.

REFERENCES