Emergent surgical cricothyroidotomy (cricothyrotomy)

INTRODUCTION — Cricothyroidotomy (also called cricothyrotomy) is a procedure in which the clinician inserts a tracheostomy tube or modified endotracheal tube through an incision in the cricothyroid membrane to establish an airway for oxygenation and ventilation.

The procedure has a controversial past. In 1909, Dr. Chevalier Jackson, a laryngologist at the Jefferson Medical School in Philadelphia, described the surgical techniques and critical factors necessary to perform cricothyroidotomy, which he called "high tracheostomy" [1]. He became famous worldwide but soon began to receive hundreds of referrals for patients who had developed tracheal stenosis following the procedure. After investigating nearly 200 of these cases, he condemned the procedure in a well-publicized paper.

Following this report, cricothyroidotomy fell out of favor until the 1970s when two physicians, Brantigan and Grow, reported a new series of 655 patients who had undergone elective cricothyroidotomy and sustained a low rate of complications, 6.1 percent overall [3]. Only eight patients (0.01 percent) developed subglottic stenosis, none of whom developed a chronic condition. Consequently, cricothyroidotomy was revisited and has become the surgical rescue technique of choice for the failed airway in adults. While debate continues regarding the merits and risks of cricothyroidotomy, these discussions have little relevance to its use as an emergency procedure [4].

Because cricothyroidotomy is a rarely performed but potentially life-saving procedure of last resort in the patient with a failed airway, clinicians responsible for airway management must retain familiarity with the necessary equipment and relevant anatomy. We suggest that emergency clinicians responsible for airway management review the anatomy and practice with the equipment needed for cricothyroidotomy several times per year.

Performance of cricothyroidotomy is reviewed here. Other aspects of difficult airway management are discussed elsewhere.

FREQUENCY — Cricothyroidotomy is rarely performed, but rates vary among different providers and settings. A five year review at one institution found that cricothyroidotomy comprises 1 percent of all intubations in the emergency department (ED) and 10.9 percent of intubations in the prehospital setting [5]. Earlier reports found a cricothyroidotomy rate of 1.7 percent for all intubations and a rate of 14.8 percent for all prehospital intubations [6,7].

One study observed a decline in the rate of cricothyroidotomies performed on trauma patients over ten years following the establishment of an emergency medicine residency training program [8]. The cricothyroidotomy rate before the residency was 1.8 percent and steadily dropped to 0.2 percent. The authors attributed the decline to several possible causes, including widespread use of rapid-sequence intubation, the presence of supervisory emergency medicine faculty 24 hours a day, and diminished concern about performing orotracheal intubation on trauma patients without first ruling out cervical spine injury by radiograph [8].

INDICATIONS — Cricothyroidotomy is indicated when an emergency airway is required and orotracheal or nasotracheal intubation is either unsuccessful or contraindicated. When the clinician cannot intubate and cannot ventilate (CICV) the patient, the swift establishment of an airway is crucial. Failure to provide oxygen to the brain within three to five minutes leads to anoxic encephalopathy and ultimately death. In a CICV scenario, placement of an extraglottic airway...
device (e.g., laryngeal mask airway) may be attempted as a rescue maneuver while preparation is made to perform a cricothyroidotomy. If oxygenation cannot be maintained, however, cricothyroidotomy is required. Management of the difficult and failed airway is discussed separately.

Conditions associated with a difficult airway that may necessitate cricothyroidotomy include massive oral or nasal hemorrhage, profound emesis, trismus, laryngospasm, airway stenosis, deformities of the oropharynx (congenital and acquired), edema of the oropharynx, foreign body obstruction, mass effect (from tumor, polyp, or web), and traumatic injuries to the oropharynx, nasopharynx, or maxillofacial structures. One study found that of all clinical conditions requiring cricothyroidotomy, 32 percent involved facial fractures, 32 percent blood or vomitus in the airway, 7 percent traumatic airway obstruction, and 11 percent failed intubation in the absence of other specified problems [8].

CONTRAINDICATIONS AND PRECAUTIONS

Absolute contraindications — Surgical cricothyroidotomy is absolutely contraindicated when the patient can be safely intubated either orally or nasally. Other absolute contraindications include complete transection of the trachea, laryngotracheal disruption with retraction of the distal trachea into the mediastinum, and fractured larynx.

Relative contraindications — Surgical cricothyroidotomy is relatively contraindicated in young children for several reasons. The airway of a child is funnel-shaped, with the narrowest part located at the cricoid ring rather than at the vocal cords. This narrowing increases the risk for developing subglottic stenosis following cricothyroidotomy.

Some believe that surgical cricothyroidotomy can damage the cricoid cartilage of young children. Since the tracheal cartilages are C-shaped, soft, and pliable in a child, the cricoid cartilage is the only circumferential support for the trachea and thus the principal structure maintaining airway patency [9]. A child's airway is smaller in diameter than an adult's and even a small amount of stenosis may cause significant impairment of air flow [10].

The preferred surgical airway technique in a young child is transtracheal ventilation using a 14 gauge needle. The age at which one can safely perform a cricothyroidotomy on a child is not well established, and recommendations vary from 5 to 12 years old [11,12].

When determining whether to perform a cricothyroidotomy, consider not only age, but other variables such as the child's size and physical maturity, state of health, external landmarks of the neck (e.g., is the cricothyroid membrane palpable?), clinical findings, and presence of trauma.

Surgical cricothyroidotomy is relatively contraindicated in a patient with a bleeding diathesis, but in a life-threatening circumstance the need to establish an airway supersedes this concern.

PREPARATION

Patient counseling and informed consent — The emergent conditions under which this procedure is performed generally preclude the discussion of risks, benefits, and complications with the patient or family.

Materials — Successful performance of a cricothyroidotomy depends on familiarity with the necessary equipment. Keep the cricothyroidotomy equipment tray simple. Only a few instruments are required. Practice using the equipment several times a year so it will be familiar during an emergency.
• IV catheter: Be certain that an IV is in place and flushing easily.
• Oxygen: Administer high flow oxygen by a nonrebreather or a bag valve mask.
• Mechanical ventilator and tubing: Be sure the ventilator is set up and a respiratory therapist is nearby to operate it.
• Yankauer suction catheter, tubing, and canister: Check that all connections are tight and suction is adequate.
• Scalpel, number 11 blade: Use the same blade for both the incision in the skin and the incision in the cricothyroid membrane.
• Tracheal hook: Handle the tracheal hook carefully when inserting and removing it. The hook's tip is sharp and can puncture the balloon on the tracheostomy tube causing a leak and necessitating replacement. The tip of the hook can also puncture a glove and skin.
• Tracheal dilator (Trousseau dilator): The dilator is used to widen the opening through the cricothyroid membrane. Unlike standard scissors or needle drivers, the dilator is opened by squeezing the handles together.
• A cuffed tracheostomy tube: The tracheostomy tube kit includes a solid white obturator. Place the obturator in the tracheostomy tube and use it to insert the tube into the trachea. After the tube is placed, remove the obturator and replace it with the open inner cannula for air exchange. In an adult a number 4 or 6 cuffed Shiley tube is used most often.

Remember that a smaller diameter increases the work of breathing and is more easily obstructed by secretions. However, the cricothyroid membrane averages only 9 mm by 30 mm, so whenever possible the outer diameter of the tube should not exceed 9 mm to avoid damage to surrounding cartilage [11,13].

A number 4 Shiley tube is a good first choice because it has an inner diameter of 5 mm and an outer diameter of 9.4 mm. A number 6 Shiley tube has an inner diameter of 6.4 mm and an outer diameter of 10.8 mm and is appropriate for a large patient.

• Alternative tube (modified endotracheal tube): If a tracheostomy tube is not available, use a modified endotracheal tube. Cut the uncuffed end of the tube to the approximate length of a tracheostomy tube. Begin with a length of 65 mm (to approximate a number 4 tube) and then adjust if necessary once the airway is secured. Attach the adapter to the newly cut end and insert the tube into the trachea, as you would a tracheostomy tube. Replace the modified endotracheal tube with a tracheostomy tube as soon as possible.
• 10 mL syringe: Test the balloon on the tracheostomy or endotracheal tube for leaks by injecting 10 mL of air.
• Cloth tie: The cloth tie included with the tracheostomy kit is used to secure the tube by making a circumferential tie around the neck.

ANATOMY — The thyroid cartilage, cricoid cartilage, and tracheal rings support and protect the airway. The vocal cords are housed within and protected by the thyroid cartilage. On the anterior neck, palpate the laryngeal prominence, which forms the superior edge of the thyroid cartilage and is popularly called the Adam's apple. It is especially prominent in men. Next, palpate the trachea and note that it is the caudal continuation of the larynx and no longer palpable as it enters the mediastinum. The trachea is comprised in large part by a row of C-shaped cartilaginous rings that are deficient posteriorly where the trachea rests against the anterior esophagus.
Next, identify and palpate the cricoid cartilage, which is a complete cartilaginous ring, shaped like a signet ring, with its widest part found posteriorly. The boundaries of the cricothyroid membrane are the thyroid cartilage superiorly, the cricoid cartilage inferiorly, and the cricothyroideus muscles laterally on both sides. Palpate the cricothyroid membrane. It is located about 2 cm caudal to the laryngeal prominence. It can be identified by a slight depression in this area. The anatomical relationship between the thyroid and cricoid cartilages and the cricothyroid membrane is the most important landmark when performing cricothyroidotomy.

The cricothyroid arteries are branches of the superior thyroid arteries that course along both sides of the cricothyroid membrane and anastomose in the midline, closer to the superior border of the membrane. Try to avoid these arteries (although this can be difficult) when performing the procedure by incising the membrane in its lower third.

PROCEDURE

Standard precautions — Use standard precautions to protect against blood and body fluid exposure. This includes gloves, face mask, protective eyewear, gown, and shoe covers. Do not break, bend, or recap needles used in the procedure.

General considerations — Place the patient in the supine position on the stretcher. Unless there is a cervical spine injury (known or suspected), extend the patient’s neck to help identify the procedural landmarks and to obtain the widest exposure of the cricothyroid membrane. While assembling the equipment for the procedure, ask an assistant (preferably the respiratory therapist) to preoxygenate the patient by administering high-flow oxygen via face mask if the patient is breathing spontaneously or via bag valve mask if not.

Analgesia and sedation — Under emergent circumstances there may not be time to administer sedative or analgesic medications. The most important goal is to secure the airway. In the case of respiratory depression or arrest, sedation may make matters worse and is not advised. However, if the patient is agitated and struggling and this behavior is impeding the progress of the procedure, a sedative or analgesic medication can be given to help control the patient.

Skin preparation — Prepare the skin of the anterior neck with an antiseptic solution (eg, povidone-iodine). If time permits, anesthetize the skin, subcutaneous tissues and the cricothyroid membrane with a local anesthetic such as 1 percent lidocaine administered through a 27 or 30 gauge needle.

Monitoring — Monitor heart rate and rhythm, blood pressure, respiratory rate, and oxygen saturation throughout the procedure. Lower the patient's gown and sheet to observe the rise and fall of the chest with respiration.
Methods

Standard technique

• Step 1: Immobilize the larynx and palpate the cricothyroid membrane - Stand at the patient's right side if you are right-handed, or at the patient's left side if you are left-handed. Immobilize the larynx with the nondominant hand and perform the procedure with the dominant hand.

The procedure is largely tactile, so proper finger position is essential. Place the thumb and long finger of the nondominant hand on either side of the thyroid cartilage to immobilize the larynx. Palpate the laryngeal prominence at the midline of the cephalad rim of the thyroid cartilage with the index finger and then move caudally 1 to 2 cm until a small depression inferior to the thyroid cartilage is encountered. This is the cricothyroid membrane. Palpate the cricoid cartilage which is at the inferior border of the cricothyroid membrane. Maintain manual control and immobilization of the larynx throughout the procedure to preserve the anatomic relationships (ie, don't let go!).

If bleeding is heavy or the patient has a large or edematous neck, it may be impossible to see the cricothyroid membrane or other landmarks during the procedure. Especially in such circumstances, proper stabilization and continuous palpation of the immobilized larynx serves as the foundation for the procedure, from which all other anatomic relationships are established. While immobilizing the larynx, the cricothyroid membrane can be palpated and the entire procedure completed by feel.

• Step 2: Incise the skin vertically - After palpating the cricothyroid membrane, make a midline, vertical incision 3 to 5 cm long through the skin overlying the membrane. The midline skin incision avoids vascular structures located laterally. The vertical orientation also enables extension of the incision superiorly or inferiorly should the initial location be too high or too low or provide inadequate access to the cricothyroid membrane. Such extension cannot be performed with a horizontal skin incision.

• Step 3: Incise the cricothyroid membrane horizontally - Make a 1 cm horizontal incision in the cricothyroid membrane over the caudal part of the membrane to avoid the vasculature running across the cephalad portion. Make the incision with care; excessive force can lead to injury of the posterior wall of the trachea. Aim the scalpel in a caudad direction to avoid the vocal cords. The cords, although surrounded by the thyroid cartilage and partially protected, are located only 0.5 to 2 cm above the cricothyroid membrane [10]. While separating the thyroid cartilage from the cricoid cartilage, be careful not to incise or fracture either one.
Once you have made the incision in the cricothyroid membrane, keep the tip of the index finger of the nondominant hand in the entry to the incision so as not to lose the opening. Continue to immobilize the larynx firmly, maintaining a triangle formed by the thumb and middle finger on opposite sides of the larynx and the index finger in the incision in the cricothyroid membrane. It is crucial not to let go at this point because there is often significant bleeding that obscures the view of the membrane.

If you are unable to stabilize the larynx because of obesity, edema, trauma, aberrant anatomy, or other reasons, you may wish to leave the scalpel in the incision until you place the tracheal hook in order not to lose the opening. In this case, be careful not to injure the back wall of the trachea with the scalpel.

- **Step 4: Insert the tracheal hook** - Place the tracheal hook under the thyroid cartilage and ask an assistant to provide upward traction.

- **Step 5: Insert the Trousseau dilator and open it to enlarge the incision vertically** - Squeeze the handles of the dilator to open its jaws. The membrane is naturally wider in the horizontal direction, which makes the vertical direction the hardest to dilate. Overcome the resistance from the thyroid cartilage as it retracts downward and the cricoid cartilage as it retracts upward against the dilator. Leave the dilator in until the tube is placed; the thyroid and cricoid cartilages will spring back into place if the dilator is removed. If a Trousseau dilator is not available, turn the scalpel around and use the handle to enlarge the incision. One study showed that a scalpel rotated 360 degrees can dilate the opening as effectively as the Trousseau dilator does [12].

- **Step 6: Insert the tracheostomy tube** - After dilating the opening, rotate the dilator 90 degrees so that the handles are pointing towards the patient's feet and insert the tube between the jaws of the Trousseau dilator. If the dilator remains in its original horizontal position, its inferior blade will prevent the tube from passing into the trachea. Once past the blades, advance the tube into the trachea. Remove the tracheal hook and Trousseau dilator. Pay particular attention not to puncture the balloon of the tube when withdrawing the sharp point of the tracheal hook.

- **Step 7: Remove the obturator** - This is the solid object with a rounded tip.
Step 8: Insert the inner cannula and inflate the balloon - 
This is the clear plastic tube with an opening for air exchange. Inflate the cuff of the tube with air from a 10 mL syringe. Inflate the balloon carefully until the balloon indicator is full but not tense; overinflation increases the risk of pressure-related injury to the tracheal mucosa.

Step 9: Attach the tracheostomy tube to the mechanical ventilator or a bag valve device - After confirming proper placement, secure the tube with a circumferential cloth tie around the neck. Use flexible connector tubing to avoid tugging and pressure on the tracheal wall.

RAPID FOUR STEP TECHNIQUE

The rapid four-step technique (RFST) can be done quickly and requires only a number 20 scalpel, tracheal hook and a cuffed tracheostomy tube. For this technique, stand at the head of the patient in the same position as when performing endotracheal intubation. Next perform the following four steps in sequence:

Step 1: Identify the cricothyroid membrane by palpation

Step 2: Make a horizontal stab incision through both skin and cricothyroid membrane with the scalpel

Step 3: Stabilize the larynx by placing the tracheal hook under the cricoid cartilage. This marks a significant change from the standard method, in which the tracheal hook is placed under the thyroid cartilage.

Step 4: Insert the tracheostomy tube into the trachea.
Seldinger technique — Cricothyroidotomy using a Seldinger technique has been described [14]. Commercial cricothyroidotomy kits are available that contain all essential equipment to perform the Seldinger technique. As an example, the Cook® Melker kit includes the following: a 6 mL syringe, an 18 gauge needle with overlying catheter, a guide wire, a tissue dilator, a modified airway catheter, and tracheostomy tape.

The procedure described here is based upon the Melker kit. Perform the procedure as follows

1. Step 1: Be certain all equipment is present and functioning. Insert the dilator into the airway catheter. Palpate the cricothyroid membrane with the index finger of the nondominant hand while immobilizing the larynx with the thumb and middle finger
2. Step 2: Attach the needle with overlying catheter (not airway catheter) to the syringe and fill it with a small amount of saline or water. Apply a small amount of negative pressure on the syringe and insert the needle carefully into the cricothyroid membrane at a 45 degree angle with the needle oriented caudad.

Be careful not to insert it too far as this may damage the posterior wall of the trachea. Watch for the appearance of bubbles in the water, indicating the needle is in the airway.

3. Step 3: When bubbles appear, remove the syringe and then remove the needle, leaving the catheter in place, with its distal tip in the trachea. Thread the guidewire through the catheter into the trachea. Remove the catheter, sliding it over the guidewire.
4. Step 4: Make a small incision in the skin at the entrance point of the guidewire with a number 15 scalpel blade.
5. Step 5: Thread the combined tissue dilator-airway catheter over the guidewire and advance it into the skin incision. Following the curve of the dilator, advance the dilator-catheter unit through the subcutaneous soft tissue and into the trachea until the cuff of the catheter is flush against the skin of the neck. A slight twisting motion may be needed.
6. Step 6: Remove the tissue dilator and guidewire as a unit, leaving the airway catheter in the trachea.
7. Step 7: Secure the airway catheter to the neck with the 'trach tape' provided in the kit or other appropriate means.

Time and ease of completion — The time to completion and ease of performing cricothyroidotomy depend upon the surgical technique, patient, setting, and the training and experience of the clinician. Emergency clinicians should be facile with at least one approach. Studies of cricothyroidotomy techniques report disparate findings.

One study found that experienced clinicians need 73 seconds and inexperienced clinicians 180 seconds to complete a cricothyroidotomy by the standard technique [15]. Another study found that clinicians took 46 seconds to complete a standard cricothyroidotomy [16].

Studies performed on preserved human cadavers found that clinicians were 88 percent successful in performing both the standard technique and the Rapid Four Step Technique (RFST), but that the RFST was faster with a mean time of 43.2 seconds compared to 133 seconds for the standard technique [14].

A study of 20 emergency physicians performing cricothyroidotomy on 200 human cadavers found that the time to tracheal puncture and first ventilation were significantly faster when cricothyroidotomy was performed using the Seldinger technique than the open surgical method.
Another study involving medical students performing cricothyroidotomy on cadavers found greater success among those using open versus percutaneous techniques [17].

**COMPLICATIONS** — Complication rates vary widely and depend upon the patient population, the clinical scenario, the clinician's level of training, and the location of the procedure (eg, emergency department, prehospital). Published reports cite complication rates between 0 and 54 percent [5,6,14,18-22]. Emergency surgical cricothyroidotomy has a much higher complication rate than elective cricothyroidotomy. This is likely because emergency cricothyroidotomy is performed on critically ill patients with difficult airways under emergent conditions. In such cases, a higher complication rate is acceptable given the risk of death if the airway cannot be established.

Bleeding occurs early and is not usually severe. To minimize bleeding, make the skin incision longitudinal in the midline to avoid lateral blood vessels. Make the cricothyroid membrane incision horizontally in the lower part of the cricothyroid membrane to avoid the right and left cricothyroid arteries that run across the superior part of the membrane and anastomose in the midline. If bleeding does occur it can usually be controlled by packing the site with gauze [19].

Other early complications include:

- Laceration of the thyroid cartilage, cricoid cartilage, or tracheal rings
- Perforation of the posterior trachea
- Unintentional tracheostomy
- Passage of the tube into an extratracheal location (ie, false tract)
- Infection

Performance of the Rapid Four Step Technique (RFST) involves lifting the cricoid cartilage, instead of the thyroid cartilage, with the tracheal hook. The cricoid cartilage is vulnerable to injury with this technique because the tracheal hook is placed under the anterior portion where it is weakest and thinnest [23].

In one study comparing complications of the RFST and the standard technique, the same overall rate of complications (38 percent) was observed for both, but the incidence of major complications (eg, complete transection of the cricoid cartilage, posterior tracheal or esophageal perforation) was 6 percent higher for the RFST [14]. Other researchers studied complications rates when both techniques were performed on cadavers [24]. They observed no complications with the standard technique but a 16.7 percent complication rate with the RFST. Four of these injuries were to the cricoid cartilage. The remaining complication was a ruptured cuff, which may be attributable to the caudal placement of the tracheal hook beside the cuff, and highlights the importance of removing the hook carefully.

Long-term complications include subglottic stenosis and voice changes. Subglottic stenosis has been associated with prolonged intubation, underlying laryngeal disease, and younger age [25].

There is limited data regarding the safety of cricothyroidotomy in patients with known or suspected cervical spine injury. A study using a cadaver model of an unstable injury at the level of the fifth cervical vertebra observed 1 to 2 mm of anterior-posterior (AP) displacement and less than 1 mm of axial compression by fluoroscopy during the performance of a standard open cricothyroidotomy [26]. The amount of movement considered safe is undetermined, making interpretation of these results difficult. Studies report a low risk of neurologic deterioration with less than 3 mm of AP displacement [27-30]. No case of neurologic deterioration or exacerbation of injury has been reported following cricothyroidotomy in trauma patients.
FOLLOW-UP CARE — Appropriate ventilator settings are made for the patient. Adequate sedation and analgesia should be provided as needed. Follow-up care for the tracheostomy tube is provided by the admitting service in consultation with surgery or otolaryngology as the case dictates.

REFERENCES


