The Cric-Key™ and Cric-Knife™: A Combined Tube-Introducer and Scalpel-Hook Open Cricothyrotomy System

Richard M. Levitan, MD

ABSTRACT

The author describes a cricothyrotomy system that consists of two devices that, packaged together, are labeled the Control-Cric™ system. The Cric-Key™ was invented to verify tracheal location during surgical airway procedures—without the need for visualization, aspiration of air, or reliance on clinicians' fine motor skills. The Cric-Knife™ combines a scalpel with an overlying sliding hook to facilitate a smooth transition from membrane incision to hook insertion and tracheal control. In a recent test versus a traditional open technique, this system had a higher success rate and was faster to implement.

Keywords: *cricothyrotomy, airway device, Cric-Key™, Cric-Knife™*

Introduction

Cricothyrotomy is a critical emergency procedure yet it rarely performed in civilian emergency settings. New intubation and ventilation devices have decreased the need for cricothyrotomy in instances of failed intubation or failed ventilation. Securing the airway through the neck remains fundamentally important in instances of severe facial injury, angioedema, and, occasionally, massive upper airway bleeding and vomitus. Despite an expanding array of airway devices, cricothyrotomy is still a crucial skill that is required in civilian trauma centers and in combat and tactical medicine. In the Iraq and Afghanistan conflicts, approximately 2% of potentially survivable injuries involved airway injuries.[1]

The procedure is not considered technically complex, but when performed by clinicians with limited surgical skills in combat situations, failure rates range between 15% and 33%.[2] Though not well documented on the battlefield, avoidance and delay of the procedure also occur; in Mabry et al.'s study of potentially survivable airway related injuries from Iraq and Afghanistan, a surgical airway was performed in only 5 of 18 cases.[1] Delay and avoidance of surgical airways also occur in hospitals. According to a national audit of anesthesia cases in the United Kingdom, "the decision to perform an emergency surgical airway was commonly inappropriately delayed."[3]

To overcome perceived and real technical issues[4] with the open procedure, numerous alternative surgical airway devices have been created.[4,5] These alternate devices involve either trocars that puncture the skin and membrane (Rusch® QuickTrach®. Cricothyrotomy Kit; Teleflex Inc. [http://www.teleflex.com/en/usa/productAreas] and Nu-Trake® Adult Emergency Cricothyrotomy Device; Mercury Medical [mercurymed.com/catalogs/ADR_CricothyrotomyKits]) or wire-guided and needle aspiration devices with dilators (Pertrach® Emergency Cricothyrotomy Trach systems; Pulmodyne, Inc. [www.pulmodyne.com/products/acute-care/pertrach/], Melker® Cricothyrotomy Set [www.QuadMed.com]). Although such devices eliminate the need to control a scalpel, trocars and needle devices can also damage the airway and vascular structures, especially if inserted off midline; distorted landmarks are common in traumatized airways.[1-5] Wire-guided and needle aspiration systems are not likely to work well when fine motor skills are compromised. In combat, deterioration in fine motor skills is believed to occur above 115 beats per minute.[6] Blood and vomitus, almost universal in battlefield situations requiring a surgical airway, make it very difficult to localize the trachea via needle aspiration Percutaneous cricothyrotomy techniques have a lower likelihood of success than do open techniques in both hospital and prehospital settings.[3,4]

Finally, any nonintuitive and infrequently used device is not likely to be used correctly.

It is interesting to note that the commonly used tools used for cricothyrotomy were not specifically designed for the procedure. Scalpels are one-sided, requiring the blade to be flipped to expand an incision. The No. 11 blade (most commonly used in hospitals) is very long relative to its narrow width and is very easy to insert too deeply (it has no stopping mechanism). Tracheostomy tubes (i.e., Shiley® [www.covidien.com/rms/products/tracheostomy]) are large and difficult to insert into the 8 to 11mm space between the cricoid and thyroid cartilages. Standard tracheal tubes are intended for oral and nasal intubation and are much too long for insertion below the vocal cords. The distance from the vocal cords to the carina averages only 11cm, while standard tubes are approximately 30cm long (i.e., they can easily wind up in the mainstem bronchi, ventilating only one lung). Standard tubes are also not easily secured to the neck (at the right depth) after insertion. Mainstem intubation is common after emergent surgical airways performed with standard tracheal tubes.[4]

A common error when performing cricothyrotomy is losing the hole after entering the trachea, and subsequent placement of the tube into the subcutaneous space.[2,4,7] Some authors have advocated use of a finger in the hole or placing the handle of a scalpel in the hole to prevent loss of the trachea.[4] An inadequately sized incision and blood pooling in the hole make correct insertion into the trachea challenging. Inserting a finger or scalpel handle into the hole after the incision is not a guaranteed solution, because such techniques still involve a transition where there is nothing in the hole. Placement of a finger, the scalpel handle, or a bougie into the hole is not instantaneous, and it is easy to create a false passage under the skin but above the trachea.

The bougie-aided cricothyrotomy, as described by Braude and others, involves initial placement of a bougie through the neck incision (and the trachea), followed by railroading a tracheal tube over the device and into the trachea.[4,7]

The bougie was conceived as a solution for tracheal tube insertion by Macintosh to aid visualization during orotracheal intubation.[8] After Macintosh's original description, it was developed by Smiths Medical (Portex® [www.smiths-medical.com/brands/portex/]) and given an up-turned or Coude tip to aid tracheal ring palpation. Although the bougie has visualization advantages in situations of difficult laryngoscopy, it does not preferentially insert into the trachea over than the esophagus when landmarks are not visually identifiable. It is long (60cm), and when holding the proximal end of the device, it is difficult to intuit the orientation of the distal up-turned tip. Placement in the tracheal is usually confirmed by tactile feedback of the tip bouncing off the tracheal rings, but this does not occur if the tip has rotated posteriorly (i.e., sliding along the smooth wall of the membranous trachea abutting the esophagus). The tracheal rings are only are present on the anterior two-thirds of the trachea. The rings are usually palpable during oral intubation because of the angle of the trachea (descending into the thorax) and the angle of bougie insertion via the mouth. In addition to palpation of the anterior tracheal rings, the bougie usually distinguishes between tracheal and esophagus placement based on depth of insertion. When inserted into the trachea, the device stops as the leading edge gets wedged into smaller and smaller bronchi; conversely, this holdup should not occur if passing into the esophagus and stomach.

Palpation of the tracheal rings is not guaranteed when using the bougie through a cricothyrotomy incision, however. The angle of insertion is very steep and the tip may not make contact with the rings. Confirmation in the trachea can usually be confirmed based on depth of insertion (it stops on reaching smaller bronchi). Disadvantages of using the bougie when performing a cricothyrotomy include its long length, adding a step between the incision and tube placement, and the potential to create a false passage on insertion.

The Cric-Key™

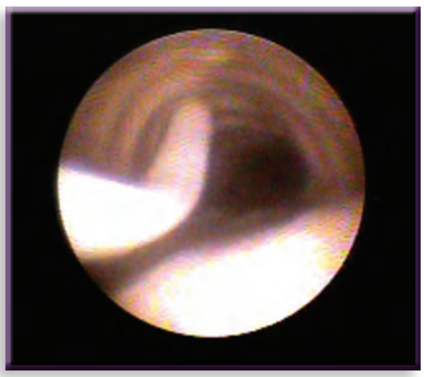
The Cric-Key was invented to verify tracheal location during surgical airway procedures—without the need for visualization, aspiration of air, or reliance on clinicians' fine motor skills. It incorporates a short curvilinear introducer and an overlying cricothyrotomy tube. The verification of placement in the trachea is by palpation of the tracheal rings, similar to a bougie during oral intubation, but it has a special shape, overall length, and rigidity specifically for cricothyrotomy.

The Cric-Key has been developed over 4 years of cadaveric testing and product engineering since the initial prototype. The initial device was formed from a 5mm steel rod of uniform shape with a shaped handle (from the same rod). Its final version has a semirigid, smooth plastic introducer and overlying cuffed 5.2mm silicone tube (Figure 1). The curvature of the device is allows insertion

Figure 1 *Cric-Key and overlying silicone, short, cuffed tube. The distal tip is rounded and deflected upward for interaction with the tracheal rings. The flattened, bend section just proximal to the distal tip allows the device to "unbend" on insertion into the trachea.*

into the cricothyrotomy incision and palpation of the tracheal rings by movement up and down within the trachea. The Cric-Key's subsequent "unbending" of the introducer on full insertion is achieved by a modification of the introducer's cross-sectional shape. Specifically, a flattened section just proximal to the distal tip allows the distal tip to "unbend" or straighten out as it is fully inserted into the trachea (Figure 2). Flattening a section of the plastic rod makes it preferentially bend easier up and down, as opposed to side to side, since the anteroposterior dimension is thinner than the left–right dimension.

Figure 2 *Endoscopic image from an optical stylet placed at the level of the vocal cords, showing the tip of the Cric-Key curving upward and interacting with the tracheal rings.*



The introducer's overall rigidity allows for lifting (on insertion) to maintain contact with the anterior trachea (i.e., verification of tracheal placement by palpation of the rings), but its flexibility allows for "unbending" and full insertion. Conversely, if the device is placed subcutaneously, lifting causes tenting of the skin (and no tactile sensation of the tip bouncing over the rings).

The length of the device is short enough that it will not go past the carina in most adults but is long enough (beyond the overlying airway tube) to permit tactile palpation of the trachea (with lifting). The overall size and weight (including the cuffed tube) make it a much smaller (and lighter) package than a standard trachea tube and bougie. It is small enough to be carried in a pocket or belt pouch.

After insertion, the introducer is withdrawn by grabbing the flared, round proximal handle of the device. The tube can be secured through two tabs alongside its proximal 15mm connector (umbilical tape, etc.) or with a supplied neck strap (for use with gloves, mittens, etc.). The tube itself has a thin profile and tear-resistant cuff and is flexible to facilitate sliding off the introducer, but it has wire reinforcement to prevent kinking.

Mabry et al.[9] recently tested military medics' airway insertion using the first metallic prototype of the Cric-Key on cadavers versus a traditional open technique. The traditional technique was successful only 66% of the time and took on average 65 seconds; the Cric-Key had a 100% success rate and only took an average of 34 seconds for tube insertion.

The Cric-Knife™

Significant challenges in performing a cricothyrotomy are to create a correctly sized incision through the membrane and to control the trachea before tube insertion. The Cric-Knife combines a scalpel with an overlying sliding hook to facilitate a smooth transition from membrane incision to hook insertion and tracheal control (Figures 3 and 4).

Figure 3 *Cric-Knife with hook in starting position (top); top and side views of hook (separated from handle).*

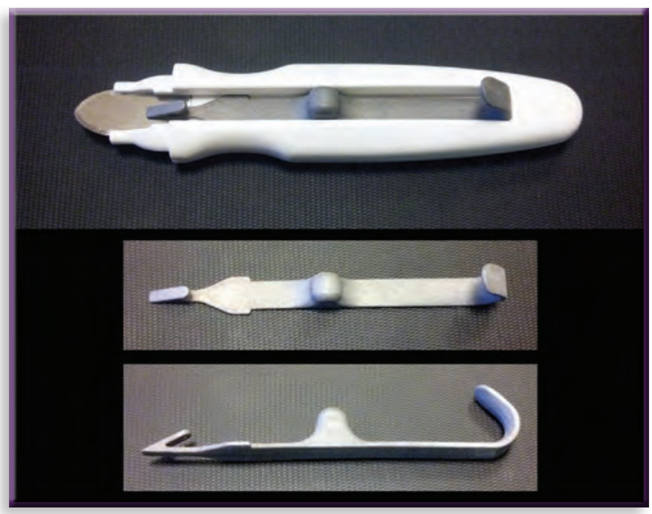


Figure 4 *Image sequence showing the leading edge of hook sliding down the handle, flush with underlying scalpel tip. The hook is advanced by the thumb, which is resting on the hook knob.*

The device is symmetric and can be used by either a right or left-hand dominant operator. The nondominant hand should stabilize the thyroid cartilage, while the dominant hand uses the Cric-Knife. The scalpel blade has a width and length intended to make a wide enough hole for tube insertion (1cm wide and long), but it is also short enough to avoid damaging the posterior structures of the airway after puncturing the cricothyroid membrane. It has a slightly rounded spade-shaped and bidirectional cutting edge. The proximal handle body has indentations on the sides for holding the device like a pencil, with the second and third fingers on the indentations. The clinician's thumb is stabilized on a rounded knob projecting up from the middle of the hook. The hook is entirely made of brushed aluminum.

The scalpel can be used in either a vertical or a horizontal orientation; in most emergent situations, it is advised to make a vertical skin incision, confirm the location of the cricothyroid membrane by palpation, and then orient the scalpel to a horizontal orientation for incising the membrane. When the location of the cricothyroid membrane is obvious, the blade can be inserted through skin and membrane together (horizontally). Whether an initial vertical or horizontal incision is made on the skin, the cricothyroid membrane is always entered horizontally with a downward motion (perpendicular to the membrane) aiming at the back wall of the cricoid cartilage (Figure 5). It is important to note that the cricoid cartilage has much larger back wall than its relatively small anterior ring. Unlike an incision at the level of the tracheal rings, where the back of the tracheal is soft, flat, and abuts the esophagus, the large back wall of the cricoid provides a firm protective stop. Also, because of the tight fit of the cricoid cartilage within the overlying thyroid, there is also a cartilaginous stop at the lateral ends of the cricothyroid membrane. This prevents extension of an incision at the cricothyroid membrane too far laterally, limiting the risk of injuring the carotid and jugular vessels. The Cric-Knife blade is short in length to prevent overinsertion (so as not to hit the posterior cricoid wall or the vocal cords), and plastic projections lateral to the blade tip are also designed to prevent excessive insertion.

After the downward incision is made with the blade, the thumb slides the hook down the handle into the hole (by moving the knob and hook down the scalpel) (Figure 6). It should be advanced fully into hole. This is felt mechanically as the leading edge of the hook passes over the scalpel and under the inferior edge of the thyroid cartilage. The hook has a tip with a triangular shape; as it is advanced into the hole, there is a distinct click once the hook passes under the thyroid cartilage. The hook slides over the scalpel and is kept flush along the scalpel by the lateral projections of the hook, which move within a channel on the handle. Once the hook has been advanced down the handle (so that it has advanced fully into the hole made by the scalpel), the hook can be lifted away from the scalpel and handle. The transition is quick and easy between the dominant hand sliding the hook down (the right thumb in the photographs) and the nondominant hand (the left hand in the photographs) grabbing the hook once it has been fully advanced. The hook has a large proximal finger hold that does not require fine motor control. The clinician now has control of the trachea with the hook, and a sufficiently large incision made by the scalpel, to allow insertion of the Cric-Key and overlying tube.

The slide of the hook over the scalpel immediately into the hole reduces the risk of losing the hole; the tip of the hook enters fully with a palpable click as it wedges under the thyroid. The shape of the handle, the hook, and

Figure 5 *Closeup view of Cric-Knife handle and hook, labeled. Note the lateral projections on the hook which ride within the channel on the handle.*

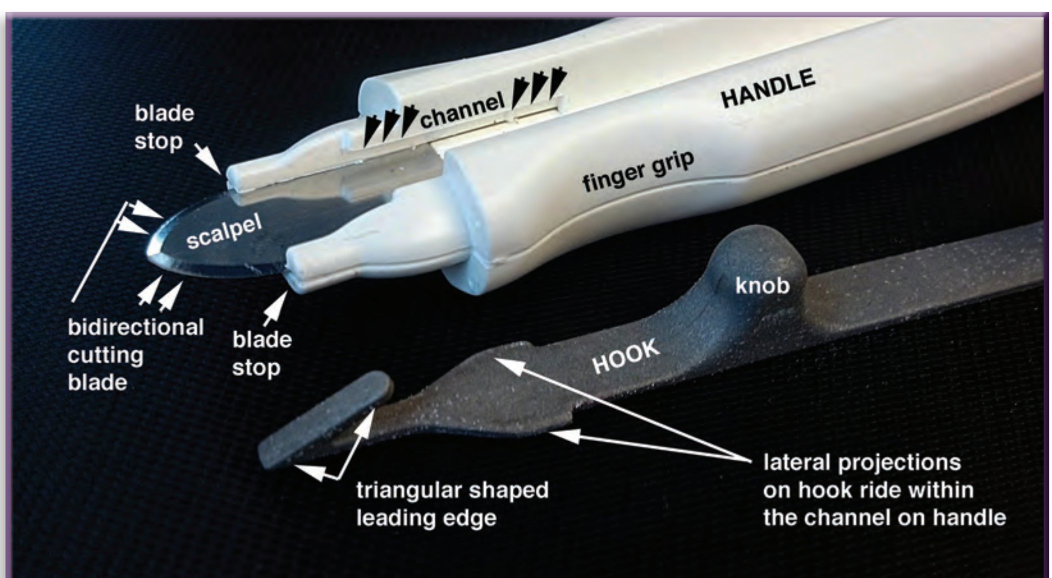
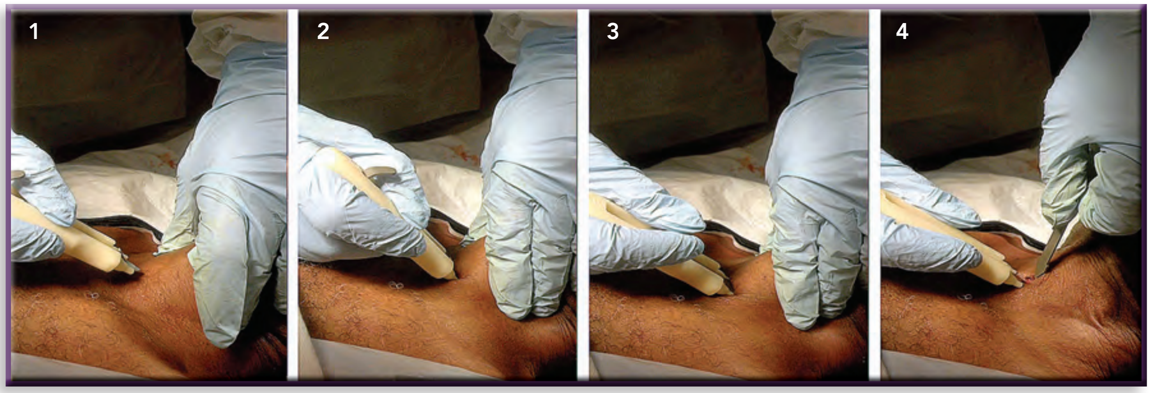


Figure 6 *Sequence of Cric-Knife operation, from left to right:* **(1)** *Stabilizing the thyroid with the nondominant hand and the dominant hand resting on sternum holding the device. Scalpel is oriented to be horizontal. [A vertical skin incision can also be used before this step, if required].* **(2)** *Horizontal stab incision (through both skin and membrane, in this instance).* **(3)** *The hook has been slid down the handle by the thumb placed over the knob, advancing the tip of the hook fully into the hole.* **(4)** *After the hook has been freed from the handle (by sliding fully down the handle), the hook is held by the nondominant hand and has control of the trachea (lifting the inferior aspect of the thyroid cartilage).*



the mechanism of sliding down the handle channel all reduce the need for fine motor control while performing the procedure.

Summary

The Cric-Key and Cric-Knife combine the basic equipment needed for an open cricothyrotomy and merge them into a more efficient and simpler system. Instead of relying on a clinician's surgical skills and fine motor control, the device is designed to facilitate easy transitions from incision to tracheal control, and then insertion of a short, cuffed tube. Combining an introducer with a tube, and the scalpel with the hook, reduces the number of separate instruments to two (as opposed to four for a separate scalpel, hook, bougie, and tube). Both devices have been specifically designed for cricothyrotomy; they are small, lightweight, robust, and intuitive, making them ideal for use in tactical and combat environments.

Disclosure

Dr. Levitan is the president of Airway Cam Technologies, Inc. (Wayne, Pennsylvania), which makes and sells educational products related to airway management. He invented the Cric-Key and Cric-Knife and receives royalties on their sale. Both devices are manufactured by Engineered Medical Systems Inc. (Indianapolis, Indiana). The devices are sold by Pulmodyne Inc. (Indianapolis) and Combat Medical Systems, Inc. (Fayettesville, North Carolina); packaged together, they are labeled the Control-Cric™ system.

References

1. Mabry RL, Edens JW, Pearse L, et al. Fatal airway injuries during Operation Enduring Freedom and Operation Iraqi Freedom. *Prehosp Emerg Care*. 2010;14:272–277.
2. Mabry RL, Frankfurt A. An analysis of battlefield cricothyrotomy in Iraq and Afghanistan. *J Spec Oper Med*. 2012; 12:17–23.
3. Cook T, Woodall N, Frerk C. NAP4: Report and Findings of the 4th National Audit Project of the Royal College of Anaesthetists.
4. Hessert MJ, Bennett BL. Optimizing emergent surgical cricothyrotomy for use in austere environments. *Wilderness Environ Med*. 2013;24:53–66.
5. Murphy C, Rooney SJ, Maharaj CH, et al. Comparison of three cuffed emergency percutaneous cricothyroidotomy devices to conventional surgical cricothyroidotomy in a porcine model. *Br J Anaesth*. 2011;106:57–64.
6. Grossman D, Christensen LW. *On combat: the psychology and physiology of deadly conflict in war and peace*. WSG Research Publications; 2004.
7. Braude D, Webb H, Stafford J, et al. The bougie aided cricothyrotomy. *Air Med J*. 2009;July–August:191–194.
8. Macintosh R. An aid to intubation. *Br Med J*. 1949;1:28.
9. Mabry RL, Nichols M, Shiner DC, et al. A comparison of two open surgical cricothyrotomy techniques by military medics using a cadaver model. *Ann Emerg Med*. 2014;63: 1–5.

Dr. Levitan is adjunct professor in the Department of Medicine, Division of Emergency Medicine, Dartmouth (Geisel) School of Medicine, Hanover, New Hampshire, and visiting professor, Emergency Medicine, University of Maryland Medical Center, Baltimore, Maryland. E-mail: airwaycam@gmail.com.