Cricothyroidotomy: A Clinical Anatomy Review

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The safe and successful performance of a cricothyroidotomy demands a working and yet specific knowledge of anatomy. An ignorance or misunderstanding of anatomy may result in failure or complications. The Educational Affairs Committee of the American Association of Clinical Anatomists has highlighted the importance of clinical anatomy for several invasive procedures. This review is building on their work and contribute further to the understanding of the anatomical framework, particularly the pitfalls and complications related to performing a cricothyroidotomy. Clin. Anat. 17:478 – 486, 2004. © 2004 Wiley-Liss, Inc.

Key words: clinical procedures; cricothyroidotomy; anatomical pitfalls; complications

INTRODUCTION

Cricothyroidotomy remains the quickest, safest, and easiest way to obtain an airway where intubation is difficult (Mace, 1988), and is a lifesaving skill where the oral and nasal route of intubation is impossible. Establishing an airway is a particularly important skill to emergency medicine clinicians. This skill is usually needed without warning. Most airway conditions present suddenly and must be dealt with immediately.

A variety of techniques in managing a patient’s airway such as head positioning, chin lift, jaw thrust, oropharyngeal, and nasopharyngeal airways as well as more advanced procedures such as orotracheal or nasotracheal intubation need to be mastered. If a patient needs rapid access below the level of the vocal cords due to obstruction above or on the level of the vocal cords, the above mentioned techniques will not be sufficient and a cricothyroidotomy, which can be safely and effectively accomplished in the emergency room, is necessary.

The advantages of a cricothyroidotomy are the speed with which the procedure can be carried out and its safety outside the operating room in contrast to a tracheostomy that should always be carried out under controlled conditions in the operating room. Boyd et al. (1979) reports that even with careful dissection for control of bleeding, a cricothyroidotomy could be done within 2 min.

Cricothyroidotomy is not carried out frequently. Many residents may not have carried out the procedure during their training, although the performance of the procedure often falls to the lot of an inexperienced resident working in the emergency room. A sound visualization of the underlying anatomy is therefore necessary to perform the procedure correctly. Walls (1988) argues that intimate familiarity with the technique and the anatomy as well as variations are the ingredients for successful performance of the procedure in most cases; a cricothyroidotomy education program is needed at the clinical anatomical level.

Ger and Evans (1993) have drawn attention to the considerably higher complication rate of a tracheostomy in the emergency situation and have suggested the cricothyroidotomy as a much lower risk procedure.

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These complications include the fact that the trachea is often found deeper in the neck than appreciated, haemorrhage due to injury to numerous surrounding veins, the presence of the isthmus of the thyroid gland, pneumothorax, and esophageal perforation.

A higher complication rate is found if the procedure is carried out in the emergency room or on the road (where proper resuscitation facilities may not be at hand) compared to an elective cricothyroidotomy. It is essentially a life-or-death procedure (Walls, 1988). Walls (1988) also advocates the use of the procedure in the emergency situation and converting it to a tracheostomy within 72 hr, thereby significantly lowering the chances of subglottic stenosis. Brantigan and Crow (1976), however, support the idea that a cricothyroidotomy can be used for the medium term management of the airway with a relatively higher risk of subglottic stenosis.

Jackson (1921) condemned the procedure in 1921 due to the high reported incidence of subglottic stenosis, but since 1976 a number of articles (Brantigan and Crow, 1976; Boyd et al., 1979; McGill et al., 1982) have reported on the efficacy of the procedure, which is also included as an important procedure in the now well known ATLS (Advanced Trauma Life Support) programs (American College of Surgeons, 1993). Bennett et al. (1996) mentioned that the use of emergency cricothyroidotomy was advanced in the Gulf War (1990–1991) as an elective prophylactic procedure to prevent fatal respiratory obstruction due to smoke inhalation injuries.

Various authors (Abrahams and Webb, 1975; McMinn et al., 1984; Beahrs et al., 1986; Crisp, 1989; Ger and Evans, 1993; American Association of Clinical Anatomists, 1999) have alluded to the crucial role of sound anatomical understanding underlying the performance of a safe and successful clinical procedure. This includes the performance of a cricothyroidotomy, a life-saving procedure usually carried out outside the controlled environment of an operating theatre. Not only the surface anatomy of the entrance of the needle, but various other pitfalls and complications are directly dependent on the understanding or lack of understanding of the anatomy (Dover et al., 1996).

Various indications (for both needle and surgical cricothyroidotomy) and contraindications are listed in Table 1. A systematic step-by-step outline of the performance of a needle and surgical cricothyroidotomy as well as two alternative methods (Toye and Weinstein, 1986; Brofeldt et al., 1996) are provided in Table 2. This review systematically focuses on the anatomical pitfalls and complications associated with the clinical anatomy during the performance of a cricothyroidotomy.
<table>
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<th>Method type</th>
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| Needle Cricothyroidotomy                | 1. Place the patient in a supine position with a non-twisted neck.  
2. Assemble a 12 or 14 gauge over the needle catheter attached to a 5-ml syringe.  
3. Surgically prepare the neck using antiseptic swabs.  
4. Identify the cricothyroid membrane, between the cricoid cartilage and the thyroid cartilage. Stabilize the trachea with the thumb and forefinger of one hand to prevent lateral movement of the trachea during performance of the procedure.  
5. Puncture the skin in the midline with the needle attached to the syringe, directly over the cricothyroid membrane. A small incision with a #20 scalpel may facilitate passage of the needle through the skin.  
6. Direct the needle at a 45-angle inferiorly to avoid injury to the vocal cords, while applying negative pressure to the syringe and carefully insert the needle through the lower half of the cricothyroid membrane.  
7. Aspiration of air signifies entry into the tracheal lumen. This is important because it assures that the posterior tracheal wall was not penetrated (thus avoiding possible massive paratracheal emphysema) and it assures that the catheter tip is not embedded in the tracheal mucosa avoiding tracheal mucosa damage.  
8. Remove the syringe and withdraw the needle while advancing the catheter downward into position, being careful not to perforate the posterior wall of the trachea.  
9. Attach the oxygen tubing over the catheter needle hub.  
10. Intermittent ventilation can be achieved by occluding the open hole. The ventilatory rate should be about 20/min, with the inspiratory phase lasting about 1 second. The expiratory phase should be at least 2 seconds. |
| Surgical Cricothyroidotomy              | 1. Place the patient in a supine position with the neck in a neutral position. Palpate the thyroid notch, cricothyroid membrane, the sternal notch and hyoid bone for orientation. Assemble the necessary equipment.  
2. Surgically prepare and anesthetize (if there is time) the area, if the patient is conscious.  
3. Stabilize the thyroid with the non-dominant hand, keeping the skin taut over the thyroid notch. This is important in order not to lose the anatomical landmarks during the procedure.  
4. Make a vertical skin incision (2cm) over the cricothyroid membrane. Locate the membrane and then carefully incise horizontally (McGill et al., 1982) (1.5cm) through the lower half of the membrane in order to avoid the cricothyroid arteries. Make sure only the tip of the scalpel blade enters the airway, to avoid injury to the posterior cricoid cartilage. The tracheal hook can be used to stabilize the larynx especially in the patient with a fat neck or hypermobile larynx.  
5. Insert the scalpel handle into the incision and rotate it 90 degrees to open the airway. Extend the incision laterally for approximately 1 cm on each side of the midline.  
6. Insert an appropriately sized, cuffed endotracheal tube or tracheotomy tube into the cricothyroid membrane incision, directing the tube distally into the trachea. The tube should always be aimed downwards in order not to injure the vocal cords above.  
7. Inflate the cuff and ventilate the patient.  
8. Observe bilateral lung inflation and auscultate the chest for adequate ventilation.  
10. Secure the endotracheal tube to the patient to prevent dislodging. |
| Rapid Four-step Technique (Brofeldt et al., 1996) | 1. Palpation: The operator is positioned at the left shoulder of the patient. Palpate the cricothyroid membrane with the left hand’s index finger. The middle finger and thumb palpate the carotid pulses and stabilize the trachea.  
2. Incision: With the right hand, make a horizontal incision over the skin. Make a subsequent horizontal incision into the inferior aspect of the cricothyroid membrane. Push the scalpel through the membrane, creating a 2.5 cm horizontal incision. This eliminates the need for an extension of the incision or spreading the incision transversely as is usually recommended.  
3. Traction: Use the left hand and place the tracheal hook through the incision made into the trachea. Turn the hook 90 degrees inferiorly and apply caudal traction to the superior margin of the cricoid cartilage with the left hand resting on the patient’s sternum.  
4. Intubation: Insert the tube with the right hand. Remove the tracheal hook and inflate the cuff. The hand motion during this method is similar to that of intubation, when using a laryngoscope in the left hand and inserting the tube with the right hand. |
| Toye and Weinstein (1986)               | Toye and Weinstein (1986) report on their success with a cricothyroidotomy device, consisting of a tube, dilator, and needle. The needle is able to split after guiding the dilator through it into the infraglottic space. The tube is then percutaneously inserted over the dilator, after which the dilator is removed. |

*aThe advantage of this method is the speed of performance, less bleeding, smaller stoma scar, less assistance, and fewer instruments are required.*
ANATOMICAL PITFALLS

Palpable Landmarks

The anterior midline structures of the neck (in order from superior to inferior: mandible, floor of the mouth, hyoid bone, thyrohyoid membrane, thyroid cartilage, cricothyroid membrane, and cricoid cartilage; Figs. 1,2) are not always easily palpable but the thyroid notch can be palpated in most patients (Stewart, 1989). The index finger can therefore be slid down on the thyroid cartilage to identify the cricothyroid membrane just inferior to the thyroid cartilage. McGill et al. (1982) stresses that identification of anatomical landmarks for successful placement includes the cricoid cartilage, thyroid cartilage, cricothyroid membrane and hyoid bone. Due to massive neck swelling emergency cricothyroidotomy may be very difficult. Simon and Brenner (1983) presented a method on localizing the hyoid bone in normal adults and children. By extending a line from the mental protuberance downward halfway the length of the distance between the mental protuberance and the angle of the mandible, the body of the hyoid bone can be located. Because the airway is suspended from the hyoid, it can locate and stabilize the larynx when performing a cricothyroidotomy in patients with neck swelling.

Cricothyroid Membrane

The cricothyroid membrane (median cricothyroid ligament; Figs. 1,2) that forms the first indentation inferior to thyroid cartilage is a dense fibro elastic trapezoidal membrane bordered laterally by the cricothyroid muscles. The medial part of the membrane is specifically referred to as the median cricothyroid ligament. This is the anatomic landmark for incision in case of cricothyroidotomy.

Fig. 1. Sagittal section of the larynx (with an orientation box in the right upper corner). 1, cricoid cartilage; 2, thyroid cartilage; 3, cricothyroid membrane; 4, epiglottis; 5, vestibular fold; 6, vocal fold; 7, tracheal cartilages; 8, infraglottic cavity. The solid arrow represents the ideal position (inferior half of the cricothyroid membrane) and direction (downward) of the placement of the needle/tube.

Fig. 2. Anterior view of the anterior midline structures of the neck (with an orientation box in the right upper corner). 1, thyroid cartilage; 2, thyroid gland; 3, cricoid cartilage; 4, cricothyroid membrane; 5, cricothyroid muscle; 6, trachea. The solid line represents the horizontal incision made over the inferior half of the cricothyroid membrane in case of a surgical cricothyroidotomy.
ament. It is the superficial, thickened anteromedial part of the conus elasticus below the laryngeal mucosa (Dover et al., 1996) and arises from the cricoid cartilage with ventral densely arranged fibres, which make the ligament clearly distinguishable from the anterior overlying tissues and the looser arranged collagenous fibres toward the airway lumen. It stretches superiorly to the thyroid and arytenoid cartilages with the free superior margin being the cord (Reidenbach, 1998). The membrane may be pierced by small blood vessels, usually situated at its attachments to the thyroid and cricoid cartilages (Reidenbach, 1998). The size of the membrane varies in adults between 22–33 mm wide (beyond the cricothyroid muscles) and 9–10 mm high (Kress and Balasubramaniam, 1982). The outer diameter of the endotracheal tube should therefore not exceed 8 mm and an inner diameter of at least 5 mm is recommended to provide good airflow (American Association of Clinical Anatomists, 1999). Dover et al. (1996) reported on the dimensions of the cricothyroid membrane in a study on 15 cadaveric specimens. The average width of the cricothyroid membrane between the cricothyroid muscles in their study was 8.2 mm and the average height 10.4 mm. The average width and height were consistently smaller in females (females: average 6.9 mm [width] by 9.5 mm [height]; males: 8.8 mm [width] by 10.9 mm [height]).

In an autopsy-based study Bennett et al. (1996) demonstrated that the vertical measurement of the cricothyroid membrane ranged from 8–19 mm (mean = 13.69 mm) and the width between the cricothyroid muscles between 9–19 mm (mean = 12.38 mm). They also showed that the vertical height measurement of the cricothyroid membrane is influenced by the synovial cricothyroid joint. Mobility can be limited in patients with rheumatoid arthritis.

**Arteries and Veins**

There are no major arteries, veins, or nerves in the area of the cricothyroid membrane. The blood supply of the larynx comes from the superior laryngeal artery, a branch of the superior thyroidal artery, as well as the inferior laryngeal artery branching from the inferior thyroid artery. There is an extensive anastomosis between these two laryngeal arteries (Bennett et al., 1996). The cricothyroid artery usually arises from the superior laryngeal artery, a branch of the superior thyroid artery. The right and left cricothyroid arteries transverse the superior part of the cricothyroid membrane and have not been found to be clinically significant for the procedure. Bennett et al. (1996) reported a 62% incidence of an artery running transversely across the cricothyroid membrane. Dover et al. (1996) reports on the cricothyroid artery arising from the superior thyroid artery in 93% of 15 cases studied. In most specimens the artery crossed the upper half of the cricothyroid membrane. The artery gives off branches, which penetrate the membrane and then run superiorly toward the thyroid cartilage. It is recommended to make the incision in the lower half of the cricothyroid membrane (Walls, 1988) along the superior border of the cricoid cartilage. This will avoid damage to the vocal cords (Bennett et al., 1996). The incision should not be made alongside the inferior border of the thyroid cartilage. In 54% of cases, the superior thyroid artery coursed anterior to the sternothyroid muscle and on the lateral border of the cricothyroid membrane. This underscores the important fact that the incision of the membrane should not extend laterally >1 cm. Dover et al. (1996) also found venous tributaries of the superior and inferior thyroid veins, crossing the cricothyroid membrane. In 80% of 15 dissections, small veins were found from the region of the thyroid isthmus crossing the cricothyroid membrane. Occasionally two cricothyroid arteries anastomose in the midline to form the median descending artery supplying a pyramidal lobe of the thyroid gland. Lateral to the cricothyroid membrane, the thyroid and cricoid cartilages are bridged by adipose tissue and delicate connective tissue, which also forms the route for blood vessels entering or leaving the larynx (Reidenbach, 1998). Further laterally the gap between the cricoid and thyroid cartilages are bridged by the cricothyroid muscles. A few vascular anomalies where a major artery crosses the neck are usually found lower in the neck. Major anomalous vessels do not overlie the cricothyroid membrane. The common carotid artery and internal jugular vein lie posterolaterally to the cricothyroid cartilage and staying in the midline will prevent injury to these structures. The anterior jugular veins run in a vertical fashion in the lateral aspect of the neck and should be uninvolved if one stays in the midline. Some authors recommend an initial vertical incision of the skin and cervical fascia to avoid these vascular structures laterally and ease identification of structures in difficult situations (Narrod et al., 1985; Walls, 1988). Thereafter the cricothyroid membrane is incised horizontally.

**Vocal Cords**

The cords are situated superiorly (Fig. 1), at least 1 cm above the site of incision (Walls, 1988). The tube should be aimed downward in order not to injure the vocal cords. The vocal cords are attached to the internal anterior surface of the thyroid cartilage. Bennett et al. (1996) demonstrated in a cadaver study that the mean distance from the upper border of the cricothyroid membrane to the vocal cords was 9.78 mm.
Anterior Cervical Fascia

An injury of this fascial layer may cause soft tissue edema to develop and make location of the cricothyroid membrane extremely difficult (Simon, 1983).

Cricoid Cartilage

The cricoid cartilage consists of an arch (anterior) and lamina (posterior) and is situated at level C6 (Fig. 1). It is the only complete cartilaginous ring in the larynx and trachea, serving as a stent and maintaining a patent airway after cricothyroidotomy (Romita et al., 1977). There is a lesser chance of injuring the esophagus during a cricothyroidotomy than with a tracheostomy due to the circumferential cricoid cartilage posterior at the level of a cricothyroidotomy (Brantigan and Crow, 1976).

Thyroid Gland and Isthmus

The isthmus is usually 1.25 cm wide, lies anterior to the second and third tracheal cartilages (Fig. 2) (Yükssel et al., 1995) and is absent in 10% of cases. The thyroid gland has a pyramidal lobe in 40% of people. Others report a 60–65% incidence and regard the lobe as a normal component of the thyroid gland (Blumberg, 1981). This lobe may extend as high as the hyoid bone and therefore may be at risk of injury when performing a cricothyroidotomy. It represents a persistent portion of the inferior end of the thyroglossal duct. The lobe is usually situated on the left of the midline. The thyroid gland descends anterior to the hyoid bone and laryngeal cartilages.

Children

The thyroid cartilage in the midline (laryngeal prominence) is difficult to palpate in children for it does not develop until adolescence. The most prominent structures are the hyoid bone and cricoid cartilage. The cricothyroid membrane is situated more cephalad in children compared to adults (Piotrowski and Moore, 1988). Because of difficulty in palpating the anatomical landmarks, it is better to do a formal tracheostomy than a cricothyroidotomy in children <5 years of age. The height of the cricothyroid membrane is not as high as in the adult (3 mm in infants compared to 9–10 mm in adults). Only a needle cricothyroidotomy is indicated for children <12 years. An endotracheal tube, which is too large, may damage the cartilage structures permanently. There is an increased risk of damaging the only completely circumferential supporting structure (cricoid cartilage) in a child, which is also the narrowest segment of the infant airway. In adults the narrowest segment of the airway is the glottic opening. The airway is also narrower and more flexible than in the adult, making posterior penetration of the tracheal wall much more likely in the child and infant. The mucosa is more fragile, looser, and softer, making edema and laceration more likely and thus cause subglottic stenosis. The risk of subglottic stenosis is reported to be higher in children and adolescents (Sise, 1984).

Complications

One needs to remember that the anatomically relevant complications listed are minor when thinking of the catastrophic morbidity associated with failure to secure an airway. This procedure is usually done in the emergency room or in the pre-hospital situation, and therefore has a higher complication rate than if the procedure is carried out electively (McGill et al., 1982; Walls, 1988). Miklus et al. (1989) report no serious complications in a retrospective analysis of 20 patients on which a cricothyroidotomy was carried out outside of the hospital on a helicopter transport team. Complication rates of between 6.1–8.6% are reported for elective cricothyroidotomies compared to 40% in the emergency room (McGill et al., 1982).

Incision Over the Thyrohyoid Space

McGill et al. (1982) found in a study of 38 cricothyroidotomies, that the most frequent complication was incorrect placement of the tube through the thyrohyoid membrane. An initial horizontal incision of the skin may contribute to misplacement of the tube through the thyrohyoid space (McGill et al., 1982). They argue that vertical incisions can be extended when necessary to get to the appropriate level of the cricothyroid space especially when the landmarks are difficult to palpate. Furthermore, proper identification of the anatomical landmarks are crucial, including the cricoid cartilage, thyroid cartilage, cricothyroid membrane, and the hyoid bone. The position of the cricothyroid membrane should always be reconfirmed after the skin incision has been made.

Intra- and Postoperative Bleeding

Evidence from cadaver-based studies shows that bleeding may actually complicate the procedure more commonly than originally recognized (Little et al., 1986). Severe bleeding is seldom encountered (Brantigan and Crow, 1976). When treating a patient in severe respiratory distress rapid and effective control of the airway is the first priority and bleeding can be dealt with secondarily. Bleeding is usually due to a superficial venous plexus injury. This can be prevented by incising directly over the cricothyroid membrane, and staying in the midline. The incision should not be extended too far laterally as bleeding usually
occurs from the edges of the incision. This complication is minimized if the skin incision is carried out vertically (Little et al., 1986). McGill et al. (1982) also report on 2 of 38 cases where haemorrhage required ligation due to horizontal incisions. The bleeders occurred at the margin of the incision and may be avoided by performing a vertical incision. Little et al. (1986) report a high number of small vessels in the region of the cricothyroid membrane at risk in a cadaver-based study. Caution should be taken not to incise the thyroid isthmus and or the pyramidal lobe of the thyroid gland if present, as they are highly vascular structures. The cricothyroid artery courses through the superior half of the cricothyroid membrane. Therefore the incision should be made through the inferior half of the membrane. McGill et al. (1982) refers to a case of fatal airway haemorrhage followed by aspiration when the cricothyroid artery was disrupted. Fatal airway haemorrhage after cricothyroidotomy has also been reported by Schillaci et al. (1976) with laceration of the cricothyroid artery with resultant endobronchial bleeding and asphyxia. Autopsy showed that this patient had a larger than normal cricothyroid artery coursing horizontally across the midportion of the membrane. These arteries run closer to the thyroid cartilage and the incision should therefore be made closer to the cricoid cartilage (Walls, 1988). Brofjeldt et al. (1996) reports on bleeding from the anterior jugular veins in one patient, which was controlled without any problem. Bleeding from the cricothyroid arteries can be controlled by ligation of the branches of the superior thyroidal artery, which may be necessary due to the extensive collateral blood supply (Schillaci et al., 1976). Donald and Bernstein (1975) report a brisk persistent endolaryngeal haemorrhage probably due to one of the vessels running in the submucosal area of the larynx in the region of the cricothyroid membrane. The endolaryngeal arteries in the submucosa of the subglottic region anastomose with the cricothyroid arteries via a perforating branch.

**Subglottic Stenosis**

Subglottic stenosis is not believed to be a common complication (Brantigan and Crow, 1982), even in the presence of laryngeal pathology. The most common cause of subglottic stenosis is endotracheal intubation (Kuriloff et al., 1989). This condition is caused by mucosal damage due to a tube eroding the mucosal surface by excessive cuff pressures, frequent tube movement and rigid tubes. This complication was seen more frequently after cricothyroidotomies when large bore tubes were used (Bennett et al., 1996). It has been said that a cricothyroidotomy tube should be removed after 72 hr due to the risk of subglottic stenosis (Walls, 1998). Sise et al. (1984) showed in a prospective analysis that there is long-term morbidity associated with cricothyroidotomy. It seems similar to that seen in tracheostomy. When comparing the complications in cricothyroidotomy and tracheostomy they are different. Subglottic stenosis due to cricothyroidotomy is reported most frequently in long-term cricothyroidotomy. It is rare in tracheostomy. But major vessel erosion and pneumothorax have been described after tracheostomy (Ger and Evans, 1993) and not after cricothyroidotomy (Brantigan and Crow, 1976; Sise et al., 1984). Ger and Evans (1993) describe the complications of tracheostomy and link these to the anatomy. Tracheostomies, especially those done below the isthmus level are prone to pneumothoraces (due to the pleura reaching 2.5 cm above the medial third of the clavicle) and there is a risk of possible injury to the brachiocephalic artery (especially in older patients with a short neck). Cricothyroidotomy therefore offers a distinct advantage due to its ease in performance. Brantigan and Crow (1976) reported no chronic subglottic stenosis in long term cricothyroidotomies, however later studies by the same authors showed that the complication was prevalent, although not high (Brantigan and Crow, 1982). This was published after the landmark article by Jackson (1921) that convinced the medical profession for nearly 40 years that the incidence of subglottic stenosis was high and the procedure should therefore be abandoned. This was appropriate in Jackson’s patient population where there were a significant number of infectious laryngeal diseases such as diphtheria, tuberculosis and Ludwig’s angina. Should a cricothyroidotomy be used for a longer period, it should only be used in patients free of acute laryngeal pathology (Brantigan and Crow, 1982). This includes an already injured larynx due to prolonged endotracheal intubation (Boyd et al., 1979). Weymuller and Cumming (1982) also suggest that a cricothyroidotomy should not be used after prolonged intubation due to the high risk of subsequent subglottic stenosis. The cricothyroidotomy stoma generally heals satisfactorily with granulation tissue and more than 50% re-epithelialization after 2 weeks (Romita et al., 1977; Boyd et al., 1979).

**Dysphonia and Hoarseness**

Dysphonia and hoarseness due to damage to the vocal cords have been reported (Gleeson et al., 1984). It may be the result of cutting the vocal cords, especially if the incision through the cricothyroid membrane is made close to the thyroid cartilage. The incision should be made along the superior border of
the cricoid cartilage (Walls, 1988; Bennett et al., 1996). Dysphonia can occur secondary to a tracheal cartilage fracture, usually due to the insertion of an oversized tube (McGill et al., 1982; Bennett et al., 1996). The outer diameter of the tube should not exceed 8 mm (McGill et al., 1982; American Association of Clinical Anatomists, 1999). A Number 4 Shiley tube has an internal diameter of 5 mm and an outer diameter of 8.5 mm. Hoarseness has been reported due to a small amount of granulation tissue below the cords secondary to cricothyroidotomy (Boyd et al., 1979). Gleeson et al. (1984) reports a high incidence of vocal disturbance after cricothyroidotomy in patients requiring a prolonged period of mechanical ventilation. Subjective vocal changes like loss of volume, a voice that fatigues easily, deep and husky voices, and limited vocal ranges have been reported. These subjective findings were found to correlate with objective analysis of laryngographs.

Laryngeal Damage

Laryngeal damage may occur due to an oversized tube being forced through the relatively small cricothyroid space. Injury to the vocal cords is associated with too vigorous superior traction on the thyroid cartilage (Brofeldt et al., 1996). This technique is suggested to expose the incision made in the cricothyroid membrane (Kress and Balasubramaniam, 1982). To avoid the risk of injury to the vocal cords, Brofeldt et al. (1996) suggest instead that traction should be applied to the inferior side of the incision on the cricoid cartilage.

Misplaced Tube Resulting in Endobronchial Intubation

A misplaced tube can be an issue when using an endotracheal tube that is inserted too deep. The tube generally goes down the right primary bronchus, which is more vertical, shorter, and has a greater diameter when compared to the left.

Aspiration

During a needle cricothyroidotomy or PTV (percutaneous transtracheal ventilation), the airway is not protected from the aspiration of upper airway secretions, blood, or emesis (Jorden, 1988).

Tracheal Stenosis

Pressure necrosis of the trachea occurs due to a high-pressure balloon cuff. A low-pressure cuff should be used.

Recurrent Laryngeal Nerve Injury

Injury to the recurrent laryngeal nerves may lead to vocal cord paralysis. The nerves lie between the trachea and the esophagus at the level of the cricoid cartilage and enter the larynx from posteriorly. Therefore, staying in the midline and taking care not to injure the posterior wall of the subglottic airway will ensure avoidance of these nerves.

Perforated Esophagus

Perforation of the esophagus is a theoretical complication (Jorden, 1988), as is the formation of a tracheo-esophageal fistula (Miklus et al., 1989). Care should be taken not to incise or push the needle too deeply after entering the infraglottic cavity.

Tracheo-Left Brachiocephalic Vein Fistula Formation

This complication may be due to unnecessary high pressure in the cuff and can be prevented by using a low-pressure cuff tube. In children, the relative shortness of the neck places the cervical and upper thoracic structures at a higher level and the brachiocephalic vein may have a cervical rather than mediastinal position (Ger and Evans, 1993).

Thyroid Cartilage Fracture

McGill et al. (1982) report a case where a longitudinal fracture occurred through the thyroid cartilage with consequent severe disphonia. This was due to an oversized tube through the cricothyroid membrane. The tube had an outer diameter of 12 mm. This is 3 mm larger than the average height of the cricothyroid membrane of 9–10 mm (Kress and Balasubramaniam, 1982). Various authors (McGill et al., 1982; American Association of Clinical Anatomists, 1999) advise that the outer diameter of the tube should not be >8 mm.

CONCLUSION

This study focuses in a systematic way on the various pitfalls and complications of a cricothyroidotomy, linking these to their indispensable anatomical framework, which include special reference to 3D relationships, functional anatomy, imaging anatomy, normal variation, and living anatomy (American Association of Clinical Anatomists, 1999). A solid knowledge of the anatomy behind a cricothyroidotomy may reduce the anxiety of physicians and paramedics performing the procedure. Anxiety exists because of the precipitous and life-threatening nature of a situation where an emergency airway needs to be established. A cricothyroidotomy remains a safe and rapid means of securing emergency airway access in the absence of contraindications. It is important to have a thorough
knowledge of the anatomy and technique as well as adequate prior practice.

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REFERENCES