Emergency cricothyrotomy

R. Vanner

Gloucestershire Royal Hospital, Gloucester GL1 3NN, UK

Summary  Emergency cricothyrotomy is the general term used to describe techniques that provide oxygen delivery directly into the trachea in the urgent or emergency situation. This will be required rarely in the general surgical patient but every anaesthetist should be conversant with a method of emergency oxygenation, and the equipment necessary should be present wherever anaesthetics are administered. The cricothyroid membrane is a common route for this form of instrumentation. Cricothyrotomy may be undertaken by needle, large purpose-made cannula or by a surgical incision and each technique has its own merits and disadvantages. Generally, a surgical cricothyrotomy is favoured by surgical specialties but anaesthetists are usually more confident with needle cricothyrotomy. However, ventilation through a small cannula or needle requires high-pressure oxygen for inflation of the lungs and exhalation has to occur through the upper airway. A large purpose-made cricothyrotomy cannula has the advantages that a standard anaesthetic breathing system can be used and that exhalation occurs through the cannula.

A larger cannula is slightly more difficult to insert but mannikins are available for training.

INDICATIONS

Oxygenation via emergency tracheal access is needed when a patient is no longer breathing (due either to upper airway obstruction or neuromuscular blocking agents), tracheal intubation fails and the patient’s lungs cannot be ventilated by facemask or other airway such as the laryngeal mask. The prevalence of this occurring after the induction of general anaesthesia is about 1 : 10 000 cases and it is, therefore, a rare event for an individual anaesthetist. Predicting difficult intubation or difficulty with mask ventilation may reduce the prevalence and misapplied or excessive cricoid force may itself obstruct the airway. In trauma the indication for emergency tracheal access is simply failed or impossible tracheal intubation. In an emergency room in Minneapolis over 3 years before 1982 there were 1362 tracheal intubations and 38 cricothyrotomies giving an incidence of one in 40 intubations. However, the nine cases of potential cervical spine injury and five cases of clenched teeth described in this report would probably have been intubated in the normal manner following recent changes in practice in the USA. Tracheal intubation following a rapid sequence induction of anaesthesia with neuromuscular blocking drugs was introduced to the emergency room in one Trauma Centre in 1994 and this reduced the incidence of cricothyrotomy from 1.8% to 0.2% both by reducing the number of failed intubations and by intubating cases with potential cervical spine injury.

In the UK, rapid sequence induction by anaesthetists has been around for far longer in the accident and emergency departments, which may explain our apparently lower incidence of emergency tracheal access. One exception is the data over 1 year from the helicopter emergency medical service (HEMS). Before reaching hospital, 143 patients required a tracheal tube, 11 (8%) of whom had a surgical cricothyrotomy. Needle, large purpose-made cannula or surgical cricothyrotomy are the techniques most commonly described for emergency trans-tracheal oxygenation. These techniques are quicker and easier to perform than a formal tracheostomy and the complications of emergency cricothyrotomy may be less serious than those of emergency tracheostomy. Contra-indications to cricothyrotomy do not exist in the emergency life-saving situation. However, the following would make the procedure more hazardous: laryngeal tumour with subglottic...
extension; recent prolonged intubation as this may cause subglottic stenosis [although probably not with small tubes of 4 mm internal diameter (ID) for short periods]; coagulopathy and an inexperienced operator.8

ANATOMY

The surface landmarks are easiest to find in the adult male and are well known to all anaesthetists. The cricothyroid ligament or membrane is subcutaneous in the midline between the strap muscles. Data from cadavers9 indicates that it is on average 8 mm (range 3–14) below the skin, 9–10 mm high and 22–30 mm wide. Medially it is ligament only and laterally there is also cricothyroid muscle, the width between the cricothyroid muscles being 9 mm. A tube inserted through this ligament must have an outside diameter of less than 8.5 mm.10 The vocal cords are 10 mm above the lower border of the thyroid cartilage. The cricothyroid artery, a branch of the superior thyroid artery, crosses the superior margin of the cricothyroid membrane as it joins its opposite number in the midline and supplies mainly the cricothyroid muscle. Fatal airway haemorrhage has occurred11 when severing this artery. Subcutaneous veins can be severed if an incision ventures too far from the midline4 and branches of the inferior thyroid vein are found over the cricothyroid membrane in six out of 10 cadavers.12 Veins of more than 2 mm diameter are found in the midline in 10% and within 10 mm each side of the midline in 30% of 107 cadavers.13 The broad posterior-lamina of the cricoid cartilage decreases the chance of needles passing through the back-wall of the trachea.

TECHNIQUES

Emergency percutaneous cricothyrotomy can be performed with either a small intravenous-type cannula (2 mm ID or less), a large cannula designed for this purpose (4 mm ID or more) or by insertion of a 6 mm ID cuffed tube by a surgical approach. The choice of technique depends on the skill and experience of the operator and on the equipment available.

Small intravenous-type cannula

The use of a small intravenous-type cannula is often termed ‘needle’ cricothyrotomy. For adult use a 14 G cannula (2 mm ID) is appropriate14 and is easy to insert. With a 10 or 20 ml syringe attached, the cannula is inserted in the midline at the inferior border of the cricothyroid ligament pointing caudally at an angle of between 30° and 45° so that the incidence of kinking is reduced.15 Once through the ligament air is aspirated to confirm placement in the trachea before advancing the cannula and withdrawing the needle. Correct placement of the cannula within the trachea should be confirmed by free aspiration of air and, if time permits, capnography which will be positive even in apnoea.16 The small cannula has a high resistance to airflow and a source of high-pressure oxygen is needed. Spoerel et al.17 showed that 400 kPa (pipeline) pressure is required to produce a flow of 500 ml/s through a 16 G cannula. Gas flow through a 14 G cannula with commonly available pressure sources and circuitry has been investigated (Table 1).18–20 A jet injector (400 kPa) provides 800 ml/s and an oxygen flow meter (400 kPa) set to 15 l/min gives 400 ml/s. Oxygen flush from an anaesthetic machine (back-bar relief valve at 32 kPa) gives 200 ml/s and an anaesthetic circuit with a bag (6 kPa) provides only 80 ml/s. When the glottis is open any pressure source lower than 400 kPa cannot inflate the lungs, whereas the high-pressure source gives a large tidal volume with entrainment of air contributing 50% which reduces oxygen concentration.18 Ideally, a jet injector at 200–400 kPa should be used with an inspiratory phase of 1 s duration with a period of at least 4 s for exhalation.

Exhalation is passive and occurs only slowly through a small cannula. Time for passive exhalation21 of 500 ml is 32 s through a 2 mm ID orifice, 8 s through a 3 mm orifice and only 4 s through a 4 mm orifice. These flows would be slower through a cannula of the same ID. It has been suggested that the insertion of another 14 G cannula (with an ID of 2 mm) would allow exhalation.22 However, as laminar flow is proportional to the radius to the power of 4, 16 14 G cannulas (2 mm ID) would be needed to give the same expiratory flow as a single cannula with 4 mm ID, which is obviously not a practicable proposition. Therefore, for adequate ventilation, exhalation must occur through the larynx and upper airway. This may be a problem if the larynx is obstructed, in which case overinflation of the lungs can easily occur with resulting barotrauma. Airway obstruction preventing exhalation can occur in 14% in emergencies.14,23 In addition to any anatomical problem with the airway there may also be oedema24 or laryngospasm.25 Laryngospasm is a real possibility in the ‘can’t intubate can’t ventilate’ scenario as the neuro-muscular blockade with suxamethonium begins to wear.

<table>
<thead>
<tr>
<th></th>
<th>Pressure (kPa)</th>
<th>Glottis closed</th>
<th>Glottis open</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet injector</td>
<td>400</td>
<td>800</td>
<td>1600</td>
</tr>
<tr>
<td>Cylinder</td>
<td>400</td>
<td>400</td>
<td>800</td>
</tr>
<tr>
<td>Oxygen flush</td>
<td>32</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td>Bag</td>
<td>6</td>
<td>80</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 1  Ventilation of a lung model (ml/s) through 14 G cannula20–22
off. However, further neuromuscular blockade in this situation could be hazardous as it would prevent the return of spontaneous respiration which might be life-saving. Airway obstruction has also been reported with jet ventilation for elective surgery.

The Ravussin 13 G cannula (VBM Medizintechnik GmbH) designed for elective trans-tracheal jet ventilation is recommended as it is less likely to kink than an intravenous cannula, and also has wings and tape for securing it around the neck (Fig. 1). The same company supplies the Manujet injector (Fig. 1). This is similar to the Sanders injector but has a variable working pressure. These systems do not measure or display the pressure within the patient’s airway and extreme caution should be exercised during the first breath with jet ventilation. The operator’s ear must be positioned over the patient’s mouth to listen for escaping gas and also the operator needs to observe the chest both for expansion and for adequate exhalation. Since exhalation occurs through the mouth, capnography cannot be utilized either for confirming that the cannula remains within the trachea or for guiding ventilation.

Most of the complications do not come from insertion of the cannula but from ventilation through it, particularly if the cannula is not, in fact, in the trachea. Kinking of the cannula occurs in 20%, misplacement causing cervical emphysema in 10%, there are problems with exhalation in 14% and pneumothorax has been reported. Cervical emphysema can cause difficulties with a subsequent surgical airway. Difficulties securing the small cannula can result in misplacement. This means that a small cannula is only ever a short-term solution (less than 1 h).

**Large purpose-made cannula**

The percutaneous insertion of a large specially designed cannula with an ID of 4 mm or more would appear to offer several advantages. Insertion can be simple but depends on the design of the cannula and the confirmation of tracheal placement can be made with the free aspiration of air or capnography. Adequate tidal volumes can be obtained using the normal pressure limits found in a conventional breathing system and reservoir bag. Exhalation occurs via the cannula into a standard breathing system and a tidal volume of 500 ml takes about 4 s allowing a respiratory rate of about 10–12 breaths/min. The capnograph should already be attached to the breathing circuit and gives a constant confirmation of correct placement and is also a guide to adequacy of ventilation. Tracheal suction of secretions and blood is possible, although if there is upper airway obstruction this may result in atelectasis.

There are very few described series of emergency cases using these cannulas but one highlighted problem is with the insertion of the Portex Minitrach II. This device was actually designed for sputum aspiration rather than an emergency airway, but it is used frequently because it is commonly available. One study found several problems—failure to insert in 17%, multiple attempts in 20%, pneumothorax in 8%, emphysema in 8% and severe bleeding in 7%. The old Minitrach II was difficult to insert as the introducer often did not find the stab incision in the cricothyroid ligament and would slide off into a para-tracheal position; in cadavers, untrained Accident Unit doctors failed to cannulate the trachea in five of 15 attempts. The newer Minitrach II has a Seldinger wire for more accurate but more time-consuming insertion. Cook’s Melker device (Fig. 2), also inserted with a Seldinger technique, performed better in a limited series of 11 cases with three complications of insertion. Chan et al. compared the insertion of the 6 mm ID Melker with surgical cricothyrotomy in a group of 15 emergency physicians who used each technique on cadavers. They had a similar insertion time of 73 s, one misplaced the Melker and two misplaced the tube surgically. The Melker had smaller incisions and also the device was preferred by 14 of the 15 physicians. Melker himself recommends a stab incision before inserting the needle so that the wire then lies within the skin incision. This will allow the dilator to pass into the airway more easily. The operator stands on the left side of the patient (if right handed), and the forefinger and thumb of the left-hand stretch and stabilize the skin over the cricothyroid membrane. The stab incision should be horizontal through the skin and inferior part of the cricothyroid membrane as a vertical incision would be more likely to cut the cricothyroid artery.

An example of a commercially available 4 mm ID cricothyrotomy cannula is the Quicktrach (VBM Medical). It is inserted with a cannula over needle technique (Fig. 3) and a detachable guard prevents laceration of the posterior wall of the airway. The only study in the literature investigates its insertion in 55 cadavers. Quicktrach was
inserted faster when a prior incision was made, and the study also found an incidence of minor laryngeal damage in 18%. In a battlefield situation, cricothyrotomy is the technique of choice for airway problems and the British Army Medical Services have elected to use Quicktrach initially with conversion to a 6 mm ID Melker tube when the patient is well oxygenated. The Seldinger wire would then be passed through the Quicktrach, the Quicktrach removed, the incision extended slightly and the Melker airway and dilator passed over the wire into the trachea. I have personally inserted a Quicktrach in the Accident and Emergency Department and oxygenation and ventilation were adequate with an anaesthetic circuit. However, I did not want to rely on this short tube during transfer of the patient to the X-ray Department for a CT scan and then to the operating theatre. I converted it into the 6 mm ID Melker device before transferring the patient. In the operating theatre there was plenty of room below this device for the surgeon to perform a tracheostomy before then transferring the patient to the ITU.

Surgical cricothyrotomy

Surgical cricothyrotomy provides a more definitive airway than the other methods. The technique is to make a 3 cm midline incision in the skin and a horizontal stab incision in the inferior part of the cricothyroid ligament. This is spread horizontally by opening scissors and spread vertically with large forceps and then a 6 mm ID cuffed tracheal tube is inserted. The complications are mainly of insertion rather than ventilation and in one study of 38 emergency surgical cricothyrotomies, 40% had complications, 13% were misplaced, 8% failed and severe bleeding occurred in 6% requiring ligation of vessels. A more recent study reported fewer complications. The long-term complications are subglottic stenosis and dysphonia if a large tube is left in for a few days. A more rapid four-step technique has recently been described with the operator standing on the left side of the patient:

1. palpation,
2. horizontal incision 2.5 cm through both skin and cricothyroid membrane,
3. lifting the cricoid by means of a cricoid hook,
4. tube insertion.

Holmes et al. compared the standard and rapid techniques performed by 32 emergency physicians on cadavers. Although the rapid technique was faster at 43 s compared to 134 s, the complication rate was higher. The large horizontal skin incision may cause excessive venous bleeding, so a report on living patients rather than cadavers must be presented before this new technique is recommended. Anaesthetists may be unhappy about performing the surgical cricothyrotomy if surgical skills, such as the ligation of vessels, are required.

OUTCOME AND FURTHER MANAGEMENT

The survival of patients after emergency cricothyrotomy is related to their co-existing condition. Pre-hospital cases have a survival of about 25%, emergency room cases have a survival of about 50% and hospital cases have a survival of 75%. One hospital series in the USA reported that if the cricothyrotomy was undertaken during cardiac arrest the survival was 6% compared to 76% for any other reason. In these series none of these patients died from the procedure itself apart from failure to achieve an airway. Emergency cricothyrotomy is a life-saving procedure with a complication rate of about 40%. Further management should include the insertion of an orogastric or nasogastric tube in cases of a full stomach. Most cases of emergency cricothyrotomy should proceed to a formal dissection tracheostomy in theatre as soon as possible, once the patient is stable. Most cases will have previous laryngeal damage or post-obstruction pulmonary oedema and therefore will require ventilation on the Intensive Therapy Unit. Although spontaneous breathing through the cricothyrotomy device is not usually an option, a useful study has calculated the extra work of breathing this would impose. An adult cannot breathe through any cannula smaller than 4 mm ID. The 4 mm
cannula doubles the normal inspiratory work. A 6 mm ID tube increases the inspiratory work by only 25%.

TRAINING

Anaesthetic departments should provide formal training of anaesthetists in failed intubation drills and cricothyrotomy, but a survey\(^4\) found that only 60% have failed intubation protocols and only 14% provide formal training in cricothyrotomy although 74% do so informally. A mannikin for cricothyrotomy practice is useful (Adam Rouilly £250) and a frozen pig’s larynx and trachea with overlying skin can also be purchased from Ventris Technical services in Cambridge (animal products must not be used in clinical areas). The best training is in the mortuary on cadavers about to undergo a Hospital post-mortem examination with the permission of a friendly pathologist and consent of the relatives. In the USA, a reduction in the incidence of cricothyrotomy\(^5\) has led to emergency physicians teaching the technique on the newly dead in the Emergency Room. The families of 51 new deaths were approached for consent, 20 families gave permission, 23 refused and eight were not asked as they were too distressed. Six weeks later 32 relatives were telephoned and only one recalled being upset at being approached.\(^6\) Anaesthetists on the intensive care unit may be very familiar with the elective percutaneous tracheostomy technique. This technique has been used in the emergency situation\(^24\) and can be performed in less than 3 min.

Availability

A telephone interview\(^29\) of doctors in 184 of the largest Accident and Emergency departments in the UK revealed that 47% were equipped for needle cricothyrotomy. 36% had larger commercially available cannula and 17% of the doctors could not locate any equipment for emergency tracheal access. At Gloucestershire Royal Hospital we have used the Quicktrach since 1993. We have 10 at various sites and they cost £62 each. They have a 5-yr shelf life and approximately one is used each year leaving one or two each year that become out-of-date to be used for training purposes. Cook’s Melker cricothyrotomy device (6 mm ID) is also available if a more secure airway is needed for transfer of the patient to theatre for a tracheostomy.

CONCLUSIONS

Each department of Anaesthesia should select a single cricothyrotomy device and this must be available at all sites that anaesthesia is given as well as in the accident unit and in the cardiac arrest box. Anaesthetists must know the sites at which the cricothyrotomy device is kept, the indications for using it, how to insert it, how to ventilate through it and how to organize further management.

REFERENCES


