

Creating Airway Management Guidelines for Casualties with Penetrating Airway Injuries

SJ Mercer¹, SE Lewis², SJ Wilson³, P Groom⁴, PF Mahoney⁵,

¹Specialist Registrar in Anaesthesia & Critical Care, University Hospital Aintree NHS Foundation Trust, Merseyside; ²Specialist Registrar in Anaesthesia & Critical Care, St George's Healthcare NHS Trust, London; ³Consultant Anaesthetist, James Paget University Hospital Foundation NHS Trust, Great Yarmouth; ⁴Consultant Anaesthetist, University Hospital Aintree NHS Foundation Trust, Merseyside; ⁵Defence Professor Anaesthesia and Critical Care, Royal Centre for Defence Medicine Birmingham Research Park, Vincent Drive, Birmingham

Abstract

Anaesthetists in the Defence Medical Services (DMS) are currently dealing with casualties who have an increased prevalence of injuries due to blast, fragmentation and gunshot wounds. Despite guidelines already existing for unanticipated difficult tracheal intubation these have been designed for a civilian population and might not be relevant for the anticipated difficult airway experienced in the deployed field hospital. In order to establish an overview of current practice, three methods of investigation were undertaken; a literature review, a survey of DMS Anaesthetists and a search of the UK Joint Theatre Trauma Database. Results are discussed in terms of anatomical site, bleeding in the airway, facial distortion, patient positioning and an anaesthetic approach. There are certain key principles that should be considered in all cases and these are considered. Potential pitfalls are discussed and our initial proposed guidelines for use in the deployed field hospital are presented.

Introduction

Combat trauma airway management is distinctive because of the increased prevalence of penetrating airway injuries [1]. The majority of UK military deployed trauma consists of blast/fragmentation injuries (53.8%) and gunshot wounds (GSW) (29.9%), in contrast to National Health Service (NHS) trauma where the bulk is blunt airway injury due to motor vehicle collisions [2]. Penetrating injuries are often dramatic with severe disruption of both soft tissue and bone [3], and airway injury is likely in ballistic and penetrating injury to the face and neck. The proximity of the carotid vessels means that penetrating carotid injury may impact airway patency. Consequently the team dealing with such injuries need to consider the likely fragment/projectile trajectory and potential airway effects.

UK Defence Medical Services (DMS) anaesthetists spend the majority of their clinical practice working with civilian patients in the NHS and will generally deploy on military operations every six to 18 months. Not only does the deployed environment have a different case mix, but clinicians are also required to use what may be unfamiliar equipment and Standard Operating Procedures (SOPs). SOPs have been developed for management of the difficult airway by the American Society of Anesthesiologists (ASA) [4], and for the unanticipated difficult airway by the Difficult Airway Society (DAS) [5]. Both protocols were designed to deal with a civilian patient population in the setting of a general hospital and do not reflect the circumstances currently encountered in the deployed military environment. Although the management of anticipated difficult airway has recently been evaluated to some extent in a civilian setting [6], we felt the unusual nature of penetrating airway injury necessitated its own SOP for use in the deployed field hospital. It is hoped that this will allow anaesthetists to improve their non-technical skills

or human factors [7] in a clinical environment that has recently been identified as exceptional by the Healthcare Commission [8].

There is a lack of literature reporting the anaesthetic management of penetrating neck injuries [9,10] with manuscripts often concentrating on surgical management [11]. Currently, there is no consensus amongst the anaesthetic community on the management of casualties with penetrating airway injuries [12] and much variability has been described [11]. We reviewed the current literature, the experience of previously deployed UK DMS anaesthetists as well as documented experience from the UK Joint Theatre Trauma Registry (JTTR) [2] and present our initial guidelines.

Methods

In order to establish a complete overview of current practice, three separate methods of investigation were undertaken.

Literature Review

The databases and search terms used to identify papers published after 1995 are summarized in Table 1. Two of the authors (SEL/SJM) evaluated each paper for relevance to the anaesthetic management of penetrating head and neck injuries and summarized any case reports.

Survey of DMS Anaesthetists

All 185 DMS Anaesthetists whose details were held on the Defence Consultant Advisor (DCA) database were contacted by e-mail on 23 November 2009. The details of any cases of blast or ballistic airway injury that they had treated were requested. This email was repeated on 23 January 2010. All cases were collated in tabular form.

Search of the UK Joint Theatre Trauma Registry (JTTR)

The UK JTTR has already been described in this journal [13] and is maintained by the Academic Department of Military Emergency Medicine at the Royal Centre for Defence Medicine. Essentially this registry contains continuous data from 2003 for

Corresponding Author: Surgeon Lieutenant Commander Simon J Mercer Royal Navy, 22 The Knowles, Blundellsands Road West, Crosby, Liverpool, L23 6AB.
Mobile number: 07970153168. Email: simonjmercer@hotmail.com

Database	Search Terms
Pubmed [14]	Ballistic airway
Sciencedirect [15]	Blast airway
Google Scholar[16]	Penetrating airway
	Laceration airway
	Fragmentation airway
	Gunshot airway
	Knife airway.
AMED	Ballistic-airway
BNI	Ballistic AND airway
EMBASE	Blast-airway
HMIC	Blast AND airway
MEDLINE	Penetrating-airway
PsycINFO	Penetrating AND airway
CINAHL	Laceration-airway
HEALTH BUSINESS ELITE	Laceration AND airway
	Fragmentation-airway
	Fragmentation AND airway
	Gunshot AND airway
	Knife AND airway

Table 1. Literature Search Terms

all casualties who trigger a trauma team activation in either the deployed field hospital or the Primary Casualty Receiving Facility afloat. Over 3000 records were interrogated for the search terms listed in Table 2. Cases identified by this search were analyzed by one of the authors (SJM) and those consisting of casualties with blast and ballistic head and neck trauma were recorded.

Search Term
Casualty Reference Numbers
Gender
Major Trauma
UK Military
Survivors
Blast Injury or Ballistic Injury
New Injury Severity Score (NISS) >16
Airway Interventions
Mechanism of Injury
Brief Incident History
Injuries
Information from free text boxes.

Table 2. Search terms used to identify cases in JTTR

Results

The literature review revealed 51 papers that were considered relevant to this study; 23 were civilian case reports and three contained military case reports. There were 17 case reports submitted by DMS Anaesthetists and the cause of injury in all cases was either GSW or Improvised Explosive Device (IED). Over 3000 were searched on the JTTR and 19 were identified of soldiers with penetrating head and neck injury. These injuries were either caused by blast (from IED, mine, mortar or rocket propelled grenade) or were due to GSW. Common themes from all three areas of investigation are summarized in headings below.

Penetrating injury though the mouth

Case reports included projectiles or objects transfixing facial structures and interfering with mouth opening. Examples included transfixion through the floor of the mouth with a bamboo cane [17], penetration of the mouth floor with a nail [18], a spear gun shaft penetrating the floor of the mouth [19] and a crossbow arrow entering under the chin and passing through the tongue, nasal cavity and between the frontal lobes [20]. Methods of management included awake fiberoptic intubation (AFOI) [17-20] rapid sequence induction of anaesthesia (RSI) [22,23] and surgical tracheostomy following failure of AFOI [19].

Injuries to the Face

Two articles summarized case series of GSW to the face from Level 1 Trauma Centres in the USA [23] and South Africa [24]. Of 73 patients in the USA case series, 36 underwent AFOI, 30 were conventionally intubated and seven had a cricothyroidotomy performed. In the South African case series there were 28 emergency orotracheal intubations (18 of which were performed in the prehospital phase), two cricothyroidotomies and six tracheostomies. The DMS survey revealed five case reports of soldiers with facial injuries as a result of IED blasts and four of these underwent uneventful RSI (one had a surgical tracheostomy performed in the prehospital phase). There were 4 case reports of GSW to the face of which two had RSI, one had a cricothyroidotomy and the other had an emergency surgical tracheostomy. The JTTR search contained three casualties who had undergone blast injuries to the face, two of which were managed by RSI and one who underwent cricothyroidotomy in the prehospital phase.

Laceration to the neck

There were several case reports of isolated neck laceration injuries [25,26] and an open laryngeal injury in a patient with multiple injuries [27]. Management included a pre-hospital cricothyroidotomy [27], surgical tracheostomy [25] and intubation directly though the defect [26,27]. There was a case report concerning a crush injury to the chest resulting in complete tracheal transection. This was managed with a surgical tracheostomy as the patient developed subcutaneous emphysema in the neck and anterior chest following orotracheal intubation [28].

Penetrating Neck Injuries

Case reports included a bullet fragment in the supraglottic region [29] and GSWs [30-32] to the neck. These were managed by orotracheal intubation [30], inhalational induction of anaesthesia [31], flexible bronchoscopy [32] and use of a light wand following failure of direct laryngoscopy [29]. Case series of penetrating neck injuries from US Trauma Centres [33,34] reported a combination of techniques including RSI, surgical tracheostomy, AFOI and orotracheal intubation without paralysis in comatose patients. A Canadian case series [11] also reported the use of AFOI and RSI. Another case series from a Level 1 Trauma Centre in the USA [35] reviewed the airway management of 89 patients with penetrating neck injuries who had undergone blind nasal intubation. The authors concluded that this technique was a valuable tool for the management of patients with penetrating neck trauma. There were three case reports in the literature of soldiers who sustained penetrating neck injuries as a result of improvised explosive devices (IEDs). Management included emergency cricothyroidotomy following failed orotracheal intubation [36],

surgical tracheostomy in the operating theatre following failed orotracheal intubation [37] and orotracheal intubation followed by surgical tracheostomy [38].

The DMS survey reported several cases of penetrating neck injury these included:

- A GSW causing damage to the posterior tracheal wall associated with bleeding into the airway, managed with a RSI.
- An IED blast to the face and neck, managed by transferring the patient to theatre in the prone position to maintain their airway. RSI was performed as soon as the patient was turned supine. A trauma surgeon was ready to perform a surgical airway if needed.
- A penetrating neck injury, managed by orotracheal intubation following gaseous induction using the Tri-service Anaesthetic Apparatus [39] with two Oxford Miniature Vaporizers filled with Sevoflurane.
- A GSW through the larynx was managed by direct intubation through the defect and then a subsequent surgical tracheostomy. A GSW injury disrupting the cricoid ring was managed with RSI.

Results from the JTTR included four cases of penetrating neck injury of which one was managed by RSI. In addition to this there were seven case reports of injury to the trachea and larynx. Of these, four patients underwent RSI, (one of which failed and required cricothyroidotomy), one received a primary surgical tracheostomy and one had an endotracheal tube placed directly through the tracheal defect.

Carotid Artery Injury

One case reported the use of AFOI to manage a penetrating neck injury tearing the common carotid artery that was causing a rapidly expanding haematoma [40]. Another case report describing a patient with neck compression due to strangulation with a chain and this was managed by conventional orotracheal intubation [41]. There was also a case report of a patient who sustained internal and external common arteries injuries following a laceration from a flying metal sheet, this was managed by intubation into the perforation of larynx [42]. A case report from the DMS survey described a casualty with a GSW to the neck associated with a laceration to the carotid artery resulting in respiratory distress and this was managed by inhalational induction of anaesthesia. There were an additional three cases of penetrating neck injury on the JTTR database (all as a result of IED blast) resulting in laceration of the carotid artery. Anaesthetic details were entered for only one of these cases, which was managed with an RSI.

Discussion

There are multiple potential approaches to the airway management of casualties penetrating injuries [43] and although the incidence is low, we felt that it was important to develop guidelines to allow planning and anticipation of these cases prior to deployment as an aide memoire. The anaesthetist may wish to base their decision making process on the clinical scenario rather than a preset algorithm taking into account their own skills and equipment available [11]. It has already been commented that most case series only contain small numbers of patients and that the injuries are diverse, meaning a didactic treatment algorithm would be unhelpful [12]. Our three different methods of investigating the anaesthetic management of penetrating airway injury resulted in a wide variety of opinions and our conclusions are enumerated below.

The anatomical site of the injury

This is a crucial consideration as penetrating neck wounds are best approached on a zonal basis [44]

Zone I - between the clavicles and the cricoid cartilage.

Zone II - between the inferior margin of the cricoid cartilage and the angle of the mandible

Zone III - between the angle of the mandible and the base of the skull.

Reference to a zone allows the prediction of potential injuries and so the potential for urgent airway management problems [12]. It should be noted that wounds in the anterior and lateral aspects of the neck compromise the airway more often than those in the posterior region [12]. Once the zone(s) involved have been identified the clinician should then consider the presence of injury to the airway's lumen (with associated blood and debris), injury within the airways wall itself or injury outside the wall (e.g. expanding haematoma or surgical emphysema). Optimal intubation conditions may be difficult to achieve and injuries may compromise positive pressure ventilation with bag-valve-mask devices [11]. Not all patients will be *in extremis* however and there may be time to consider additional investigations to characterise the injury. CT is considered the first-line investigation in stable patients with penetrating neck injuries [45] to identify the location, nature and extent of any airway injury.

Airway bleeding/facial distortion and patient positioning

Blood and debris may be soiling the airway and if the casualty is maintaining their airway satisfactorily they do not require immediate airway intervention apart from a jaw thrust. They should be allowed to adopt their most comfortable position. Lateral, sitting and prone positions have all been described in case reports and the importance of this must be reinforced during patient handover.

Anaesthetic approaches to penetrating airway injury

The principle clinical features mandating early tracheal intubation are acute or worsening respiratory distress, an airway that is compromised by blood and secretions, extensive surgical emphysema, tracheal deviation by haematoma and a decreasing level of consciousness [46]. Although anaesthetists perform endotracheal intubation routinely, it should be approached with great caution in a patient with a penetrating airway injury [47].

Direct Laryngoscopy/ Rapid Sequence Induction (RSI)

It is important that anaesthetists are aware that despite the laryngeal inlet appearing intact, there may be a tracheal tear present below this and placing an endotracheal tube under direct laryngoscopic vision could lead to the tip passing through the defect. This may go unrecognized and risks airway obstruction, pneumomediastinum and the creation of a false passage [47] as this is in effect a 'blind technique', which may completely disrupt the larynx. The incidence of these phenomena is unknown but is most likely lethal and difficult to reverse even with an emergency surgical airway (especially if gross surgical emphysema has been created) [12]. Others recommend an 'awake look' under topical anaesthesia but this will obviously not indicate if there are any injuries distal to the vocal cords [11].

Some authors hold that RSI should be the default method of airway control [48]. Evidence is available to suggest that it is safe [49] and has a high success rate [33,34,50]. Despite this, there are others who argue against RSI in certain cases [36,37], where the

airway is penetrated below the vocal cords (risking unrecognized misplacement of the ETT). It is also not recommended in cases of near or total airway transection, where paralysis will abolish the supportive muscle tone, which may be all that is holding the airway together [11,51]. For these reasons, some authors actively support the casualty maintaining spontaneous ventilation at all costs [47]. Current UK anaesthetic practice includes the use of cricoid pressure [52] during an RSI but this may distort the airway, change the anaesthetist's view and result in a more difficult airway [47,53].

Blind Nasal Intubation

The consensus of opinion is that blind intubation methods including blind nasotracheal intubation should not be used in patients with penetrating neck injury because further injury or complete airway obstruction may be induced [54]. A single paper reviewing a case series of patients successfully managed with blind nasotracheal intubation has challenged this advice [35]. As this technique is rarely taught in UK hospitals, we would discourage its use by clinicians for whom it is not part of their regular practice. It also requires extension at of the upper cervical spine while the lower cervical spine is extended, as part of the technique, which may risk neurological injury in the unstable cervical spine in trauma.

Fiberoptic Intubation

AFOI is the gold standard for safely securing the airway in a casualty with a traumatic airway injury. This technique allows the lumen of the airway to be identified by direct vision throughout the intubating process and allows the anaesthetist to be confident about siting the endotracheal tube (ETT) distal to any visualized tear.

This technique depends on availability of a fiberscope, the co-operation of the patient [47,55] and the skills of the operator. Another confounding factor to this method of securing the airway is that any foreign bodies or blood will hinder the use of the fiberscope [47] although in skilled hands it has proved very effective [17-20, 23,24,40]. Difficulties regarding AFOI in the field hospital also arise from the sterilization aspect of the fiberscope, however recently disposable versions have been developed, but are yet to be evaluated in this setting.

Surgical Airway

A case could be made to consider surgical airway as the first choice intervention for laryngeal injuries [47,56] as it is done under direct vision reducing the potential for worsening an injury by misplacement the endotracheal tube. Both cricothyroidotomy and tracheostomy have been described as safe techniques to perform in an awake, spontaneously ventilating patient with local anaesthetic infiltration [47]. Cricothyroidotomy itself has further been described as a safe, rapid technique of obtaining an airway in an emergency setting [57]. Tracheostomy should be performed at least one tracheal ring below the injury to avoid complications [12]. Whenever a difficult intubation is suspected it is advisable to have the patient's neck prepared and the surgeon ready to perform a surgical airway [47]. The anaesthetist should be mindful that the rapid creation of a surgical airway might be a difficult task for the surgeon, particularly if there is overlying haematoma or other gross anatomical disruption.

Recommendations

Despite the variety of anaesthetic management strategies present in the literature, there are certain key principles we believe should be considered in all cases. These are listed in Table 3. Human

factors play an important role in ensuring that individuals in a clinical team perform to the highest standard [58]. We believe that the principles of Anaesthesia Crisis Resource Management (ACRM) [59] are crucial to ensuring the best possible outcome when faced with a patient with severe blast or ballistic injuries.

Monitor patient with full AAGBI standard monitoring [60] (especially ET_{CO}₂)

Preoxygenation (even in patients with marginal functional reserve [43,47,54])

Airway optimization

- If conscious allow patient to adopt most comfortable position [46].
- If unconscious use jaw thrust

Consider the urgency with which a secure airway is required

Consider the site of injury

Availability of suction (preferably two devices)

Table 3. Key principles to consider for all casualties with a penetrating airway injury

Potential Pitfalls

The literature review and DMS Anaesthetists experience and JTTR search have enabled us to suggest certain pitfalls when dealing with patients with penetrating airway injuries. These should be considered when constructing a plan of securing the airway and are listed in Table 4.

Ventilation: Positive pressure ventilation risks enlarging tears and causing surgical emphysema

- **Try to preserve spontaneous ventilation prior to intubation**
- Use bag-valve-mask ventilation is a last resort
- Avoid LMA in injuries distal to cords
- Avoid transtracheal jet ventilation

Intubation: Blind placement of the tube risks the tip passing through the defect and lying outside the airway and is only avoided by fiberoptic intubation or a surgical airway.

Intubation: Endotracheal intubation should be approached with caution

- **Avoid oral intubation when the injury is distal to the vocal cords**
- **Avoid blind nasal intubation**
- **Fiberoptic intubation is likely to be difficult/impossible when there is bleeding into the airway**

Surgical Airway

- Is potentially extremely difficult in face of subcutaneous emphysema or an expanding haematoma (direct laryngoscopy is also likely to also be difficult).

Drugs: Avoid muscle relaxants in near/complete airway transection

- **Muscle tone may be important for airway integrity**

Table 4 Potential Pitfalls to consider when drawing up plans to secure the airway.

In proposing initial guidelines for DMS anaesthetists, we have been strongly influenced by the comments made in the review article by Abernathy [47] regarding the placing of an endotracheal tube when a distal airway injury has not been excluded. In such cases a primary surgical airway may be the most appropriate plan [43]. Whether it is the anaesthetist or the trauma surgeon who performs this will be decided by the skills and experience of the individuals within the team.

Our initial guidelines based on site of injury are summarized in Table 5. We anticipate that this preliminary work will now lead to further studies to develop guidelines and training systems. We also hope to work with national bodies such as the Difficult Airway Society to further develop our guidelines.

Zone I injury

- Consider direct intubation through a large defect
- Consider tracheostomy
- Consider a thoracotomy in complete tracheal transection [62]

Zone II injury

- Consider a CT scan to exclude distal airway injury
 - (Provided that there is no immediate impending obstruction of the airway).
- Consider oral intubation by RSI for injuries proximal to the larynx
- Consider fiberoptic intubation for injuries distal to the larynx
- Consider a surgical airway for injuries distal to the larynx

Zone III injury

- Consider oral intubation by RSI for small defects
- Consider surgical airway for gross disruption.

For any large airway defect

- Consider direct intubation through the defect

Table 5 Suggested Guidelines for the Airway Management of Penetrating Airway Injury

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