**Title Page**

**Title:** A Systematic Review of The Anaesthetic Management of Non-Iatrogenic Acute Adult Airway Trauma.

**Short Title:** The Anaesthetic Management of Non-Iatrogenic Acute Adult Airway Trauma

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**Summary**

**Introduction**

Non-iatrogenic trauma to the airway is rare and presents a significant challenge to the anaesthetist. Although guidelines for the management of the unanticipated difficult airway have been published, these do not make provision for the ‘anticipated’ difficult airway. This systematic review aims to inform best practice and suggest management options for different injury patterns.

**Methods**

A literature search was conducted using Embase, Medline and Google Scholar for papers after the year 2000 reporting on the acute airway management of adult patients who suffered airway trauma. Our protocol and search strategy are registered with and published by PROSPERO ([http://www.crd.york.ac.uk/PROSPERO](http://www.crd.york.ac.uk/prospero), ID: CRD42016032763)

**Results**

A systematic literature search yielded 578 articles, of which a total of 148 full text papers were reviewed. We present our results categorised by mechanism of injury: blunt, penetrating, blast, and burns.

**Conclusion**

The hallmark of airway management with trauma to the airway is the maintenance of spontaneous ventilation, intubation under direct vision to avoid the creation of a false passage, and the avoidance of both intermittent positive pressure ventilation, and cricoid pressure (the latter for laryngotracheal trauma only) during a rapid sequence induction. Management depends on available resources and time to perform airway assessment, investigations and intervention (patients will fall into one of three categories: no time, some time, adequate time). Human Factors, particularly the development of a shared mental model amongst the trauma team, are vital to mitigate risk and improve patient safety.

**Keywords**

**Airway Management**

**Blast Injuries**

**Blunt injuries**

**Burns**

**Wounds, Penetrating**

**Introduction**

Trauma to the airway may cause acutely life-threatening airway laceration, obstruction, haemorrhage, and aspiration of blood; this presents the anaesthetist with a major challenge 1 2. Fortunately, airway trauma is a relatively infrequent complication of major trauma; both in the UK civilian (NHS) and UK-Defence Medical Services settings3 4. However, complications related to this injury can be catastrophic without optimal management. For example, in a case of blunt or penetrating airway trauma, advancing a bougie or endotracheal tube blindly beyond the vocal cords risks penetration through an airway laceration, leading to airway obstruction, pneumomediastinum and the creation of a false passage1 5. Guidelines for the management of the unanticipated difficult airway have recently been revised by the Difficult Airway Society6 these however do not make provision for an ‘anticipated’ difficult airway that could be experienced in complex trauma and if followed could even worsen the traumatic airway. Our aim was to inform best practice for airway trauma and suggest management options for the various injuries patterns to reduce serious sequelae.

**Methods**

**Search Strategy**

We searched Embase, Medline and Google Scholar for papers reporting on the acute airway management of adult patients who had suffered airway trauma. We limited the search to articles published from the year 2000 onwards to represent contemporary practice. The search included full text reports of articles from peer-reviewed journals and conference abstracts published in English and there were no restrictions to the studies reviewed. In addition, reference list of the articles reviewed were scrutinized for additional relevant articles and book chapters.

**Article selection**

Titles and abstracts of the references obtained were reviewed by two independent reviewers (MB, CJ). Articles were categorized as for inclusion or exclusion. Articles were removed if both reviewers agreed independently to exclude. In the event of agreement to include or a discordant opinion, articles were reviewed in full by one of four independent reviewers (CJ, PG, EC and SJM). Inclusion criteria was Adults older than 18 years of age with airway trauma, papers published on or after 2000 and paper reporting airway trauma (blunt, burns, penetrating, blast or miscellaneous) and anaesthetic management. The exclusion criteria were children (<18 years), animal studies, papers not dealing with acute trauma and airway trauma and papers that did not have an airway management focus. Our full protocol and search strategy are registered with and published by PROSPERO ([http://www.crd.york.ac.uk/PROSPERO](http://www.crd.york.ac.uk/prospero), ID: CRD42016032763) this includes the search terms and keywords used.

**Results**

Our systematic literature search yielded 578 articles (see Figure 1). Two hundred and sixteen were excluded after title review. After abstract review a further 214 articles were excluded. A total of 148 full text papers were reviewed of which we included 35 in this review. Figure 1 details reasons for inclusion and exclusion. We present our results categorised by mechanism of injury: blunt, penetrating, blast, and burns.

[Figure 1 Here]

**Blunt Injury**

Blunt airway trauma usually involves high-energy transfer; examples include: assault, crush, fall from height, road traffic collision, pedestrian versus vehicle, hanging, accidental strangulation and the 'clothesline' mechanism. Table 1 describes the various mechanisms of injury in blunt trauma and their associated injuries.

[Table 1 Here]

Patients who suffer blunt injury develop complex airway injuries, often as part of severe multisystem trauma. Failure to intubate, secure and protect the airway in these patients are common factors that lead to an increase in morbidity and mortality7-9. Blunt airway trauma includes maxillofacial, laryngotracheal trauma and disruption of the trachea and bronchi. The sternum, cervical spine and mandible shield the airway during trauma such that the incidence of blunt airway injury is low (~0.4%7-9). Despite being a rare pathology, the impact can be significant with mortality rates of traumatic lesions below the vocal cords quoted as high as 63%10. Bronchus disruption occurs in 1% of chest trauma; most of these patients die at scene11.

Maxillofacial trauma is the most common type of blunt airway trauma but does not usually present a problem as trismus is usually due to pain and therefore resolves on induction. The main issues to consider are then airway haemorrhage, hypoxia and the risk of aspiration. Very rarely trismus is due to impaction of a condylar head fracture causing a physical obstruction to mouth opening, which only becomes apparent after rapid sequence induction12.

The cricoid cartilage and cricothyroid membrane are involved in 50% of cases of blunt airway trauma with airway compromise; injury to the thyrohyoid membrane, thyroid cartilage and extrathoracic trachea account for the remainder 1 13. Laryngotracheal separation occurs in up to 63% of cases usually between the cricoid and 4th tracheal cartilage 14 15. The airway can remain patent if spontaneous respiration is maintained by splinting of peri-tracheal connective tissue16. This situation is precarious and can deteriorate rapidly17.

Blunt trauma at the level of the larynx or below can be difficult to diagnose and life threatening if managed poorly. Patients can present with non-specific signs and symptoms such as cough, dyspnoea, aphonia, stridor, laryngeal crepitus, haemoptysis and subcutaneous emphysema. These symptoms do not correlate well with anatomical site of the lesion14 15, however complaints of haemoptysis and stridor at presentation have been associated with severity of injury16 18.

In view of the poor relationship between signs and severity of injury, the clinician must have both a high index of suspicion and a low threshold for further investigations, including plain x-rays (chest and lateral c-spine) to rule out surgical emphysema and/ or a pneumothorax. Nasendoscopy is useful and permits assessment of vocal cord movement, integrity of laryngeal mucosa and airway patency13. Computed Tomography is the gold standard and detects the site of injury in 94% of blunt trauma19. Bronchoscopy is considered the best diagnostic tool for suspected lesions below the vocal cords 11 14 20, but utility in acute airway compromise is limited because it is a skilled technique and access to equipment may be limited. The severity of blunt airway trauma has been classified by Schaefer21 (Table 2).

[Table 2 Here]

Trauma to the upper and lower respiratory tract should be managed on a case-by-case basis: minor cases of blunt airway should be observed on the critical care unit with reassessment of the airway at regular intervals for at least 48 hours. The management of major blunt airway trauma is governed by the degree of patient co-operation and a risk-benefit analysis. The safest approach to patients requiring intubation is to instrument the trachea under direct vision to avoid entering a tear, creating a false passage or disrupting the airway completely1. It is preferable to do this with the patient awake and breathing spontaneously.

Following these principles there are three judicious approaches to airway management:Performing an awake tracheostomy under local anaesthesia is a common intervention of choice for laryngotracheal trauma 18. However, this technique requires a high degree of operator skill, may be difficult, is limited by patient cooperation and time taken to assemble skilled assistance16 22 23. It is important to note that surgical cricothyroidotomy and percutaneous cricothyroidotomy are contraindicated in these patients as they may lead to further airway disruption11 18 24. This is not the case for trache0-bronchial trauma as the lesion is commonly more distal, with 76% of injuries occurring within 2 centimetres of the carina, and 43% occurring within the first 2 centimetres of the right main bronchus25 26.

Awake fibreoptic intubation is an alternative technique, thismaintains spontaneous ventilation, allows simultaneous airway assessment and placement of an endotracheal tube distal to any peri-carinal defect 22 23. Care must be taken when railroading the endotracheal tube so its bevel does not catch on a tear extending the injury27. This can be avoided by using a lubricated small diameter tube, fitting snuggly onto the scope and twisting the tube so its bevel faces any lesion during its advancement into the trachea. The use of the Lightwand in blunt trauma has also been described28.

Conventional intubation is a rapid way of securing the airway but risks intubating a tear, creating a false passage or disruption of the larynx or trachea21 29. Consequently, we recommend fiberscope assisted direct or video laryngoscopy as part of a modified rapid sequence induction (with no cricoid pressure or positive pressure ventilation as both may aggravate the injury30 31). A small diameter endotracheal tube should be placed at the introitus of the larynx under direct vision and then a fiberscope is passed through the tube and into the trachea. The endotracheal tube can then be delivered past the lesion safely if the bevel is orientated to face the lesion.Modified rapid sequence induction and rigid bronchoscopy is an alternative choice as airway inspection is simultaneous with intubation. This technique requires a high degree of operator skill and needs appropriately trained personnel but can deal effectively with distal tracheal or bronchial disruption11 18 32. A summary of the associated problems and cautions in relation to the anatomical territory is summarized in Table 3. Technique of choice depends upon patient’s condition, urgency, and experience of anesthesiologist and surgeon33.

[TABLE 3 HERE]

**Penetrating and blast Injury**

Penetrating injuries to the face and neck are uncommon in both civilian25 34 and military 3 35 populations. However, incidence is increasing in military personnel as modern body armour does not protect the face and neck 26 34 36-38. Airway wounds can cause immediate life-threatening compromise34 because of the density of vital structures within the neck1 2 39 40. Indeed, on exploration, a clinically superficial stab wound may reveal a vascular or aerodigestive injury 3 4 32. Blast induced injuries result from direct or indirect exposure to an explosion and have high potential for an associated upper airway injury, 5 34 41 the most severe is complete disruption of the airway. 1 35 42.

The causes of penetrating airway trauma are diverse and include assault or self-inflicted injuries with firearms or knives 36-38 40. Facial wounds are usually due to gunshot 2 7 9 38 39 43-46  or blast injuries 4 10 47-55. Objects or projectiles can transfix the mouth and limit mouth opening 11-15, 25, 34, 40-46 56, 57. Patients may also present with neck lacerations and open wounds to the airway 2 16 38 40. Gunshot and blast injuries result in penetrating neck trauma25 47-55 so always consider the likely trajectory of projectiles or fragments and their potential airway effects. The location of great vessels in the neck adjacent to the airway means haemorrhage can impact airway patency 14 15 56 58 with high mortality 16 18 34 43 45 46 56

When assessing these patients an effective approach is to divide the structures of the head and neck into three zones 13 39 57. Zone one: clavicles to the cricoid cartilage, zone 2: cricoid cartilage to the angle of the mandible and zone 3: angle of the mandible to the base of the skull. Zone analysis predicts potential injuries and need for urgent airway management problems 5 19 25. Blood loss and upper airway obstruction are the major determinants of injury severity 14 38 40.

Wounds in the anterior and lateral aspects of the neck compromise the airway more often than those in the posterior region11 20 25 40 42. The clinician should also consider the presence of blood and debris within the lumen of the airway, injury within the airway’s wall itself or injury outside the wall (e.g. expanding haematoma or surgical emphysema). If possible, CT is the first-line investigation in stable patients with penetrating neck injuries21 35 58 to identify the location of an airway injury.

As with blunt injuries, major penetrating and blast airway trauma management is governed by the degree of patient cooperation and a risk-benefit analysis. Potential difficulties to consider are: neck haematoma or subcutaneous emphysema around the airway that can distort anatomy and impair tracheostomy. Fibreoptic intubation is difficult if blood or debris are present within the airway. Regardless, awake fibreoptic intubation in skilled hands has proven effective1 18 39 41 43 45 46 56  59.

The literature suggests that the safest approach to patients requiring intubation is to instrument the trachea under direct vision to avoid entering a tear, creating a false passage or disrupting the airway completely5 16 22 23 52 60. It is preferable to do this with the patient awake and breathing spontaneously. Similar to blunt trauma, awake tracheostomy is the intervention of choice 5 11 18 22 23 25 26 35 38 40 42 61-66 andsurgical or percutaneous cricothyroidotomy are contraindicated27 61. It is important to consider thoracotomy if a patient presents with chest trauma and low tracheal or bronchial transection standard tracheostomy in this situation will result in malposition distal to the defect. Awake fibreoptic intubation is an alternative option to permit simultaneous airway assessment and placement of an endotracheal tube distal to any laceration 21 29 41 46 59 67 68. As emphasised previously great care must be taken when railroading the endotracheal tube so its bevel does not extend a laceration. A modified rapid sequence induction and fibreoptic assisted direct or video laryngoscopy may be undertaken if a general anaesthetic must be administered immediately. However, the clinician should avoid muscle relaxants (muscle tone may be important for airway integrity in airway transection 30 52 60 69) and be cognizant that conventional intubation risks intubating a tear 5 31 70. We suggest that this may be mediated by fiberscope assisted direct or video laryngoscopy as part of a modified rapid sequence induction (with no cricoid pressure or positive pressure ventilation). An endotracheal tube should be placed above the vocal cords under direct vision and then a fiberscope passed through the tube and into the trachea. The endotracheal tube can then be delivered safely as described above. Large neck wounds can be intubated directly over a fibrescope in this manner. Combined usage of an Airway Scope and gum elastic bougie for emergency airway management in a patient with neck stab wound has also been described71 , as has the use of the AirTraq in traumatic asphyxiation72 and the use of the Lightwand28. A summary of the associated problems and cautions in relation to the anatomical territory for non-iatrogenic injury to the airway caused by penetrating injury is summarized in Table 4.

[Table 4 Here]

**Burns**

Burns to the upper airway caused by direct heat and steam injury, electrocution or contact with corrosive chemicals can lead to marked swelling of the face, tongue, epiglottis, glottis, and result in airway obstruction11 18 25 32 34 62 63-66 73. Airway swelling may not occur immediately but may develop over a period of hours (exacerbated by fluid resuscitation). Therefore, a high index of suspicion and frequent re-evaluation of the airway are essential3 35 67 74-76. Thermal injury is primarily restricted to structures above the vocal cords, unless steam is inhaled because the oropharynx and nasopharynx acts as an efficient heat sink26 34 36-38 68 76. Smoke inhalation delivers a pathologic insult to the lungs as a result of the particulates, respiratory irritants and systemic toxins that it contains 34 77. In this context it is necessary to look for and treat carbon monoxide78 and cyanide poisoning79.

Inhalation injury is a greater contributor to overall morbidity and mortality than either body surface area percentage or age59 69 and is present in 60% of central facial burns63 70. Burns patients without smoke inhalation have a mortality of 2% compared to a mortality of 30% with this type of injury80.

Patients that present acutely with facial and neck burns have two predominant airway issues: airway obstruction and smoke inhalation. These risks prompt the early intubation of high risk patients 77 81 82 as the rate of difficult intubation increases from 11.2% to 16.9% if delayed (due to the development of airway oedema)63 64 73 83. However, intubation is not without risk and the clinician should carefully weigh individual cases 74-76 84. Nasendoscopy is an important tool to diagnose the extent and severity of an airway burn and serial nasendoscopy of vocal fold oedema has been used to predict the need for intubation in at risk patients68 76. Fibreoptic bronchoscopy supports the diagnosis of smoke inhalation and may reveal carbonaceous debris, erythema or ulceration.

Intubation is mandated in cases of heat and smoke inhalation injury combined with facial, neck or extensive body burns. In contrast, physiologically stable patients with smoke inhalation injury but no facial or neck burns may be monitored by nasal endoscopy and intubated later 59. In addition to airway oedema other causes of difficulty include limited mouth opening and intractable trismus in electrical burns63. Mask ventilation may also be challenging due to the presence of dressings and exudates 42 80 and the application of nasal oxygen should be considered. This can significantly boost the effective inspired oxygen and can be left on during tracheal intubation attempts. The application of additional nasal oxygen during intubation has been termed NO DESAT)85.

For an anticipated difficult airway, clinical examination and nasendoscopy will provide vital information, however, this does depend on the degree of patient co-operation and the severity of the injury. Minor cases can be managed conservatively in a monitored (HDU) setting. For major burns requiring immediate treatment for co-operative patients awake fibreoptic intubation should be considered if the preoperative evaluation reveals concern for upper airway patency or difficult mask ventilation81. In severe or non-compliant cases, a primary surgical airway is mandated63 64 83. Tracheostomy may also be indicated if a laryngeal injury is suspected 84 86. In the uncooperative or those with less severe pathology on clinical examination and nasendoscopy, rapid sequence induction followed by videolaryngoscopy is appropriate. One paper described the use of the combitube in the airway management of burns patients87.

After intubation, secure the tube carefully as accidental extubation may have fatal consequences88. Fixation methods include wiring the tube to a tooth and the use of archbars. Leave the endotracheal tube uncut as facial swelling can cause it to retreat into the oropharynx, requiring re-intubation at the worst possible time. A summary of the associated problems and cautions in relation to the anatomical territory for non-iatrogenic injury to the airway caused by burns injury is summarized in Table 5.

[Table 5 Here]

**Conclusion**

Our systemic review of the literature on acute adult non-iatrogenic airway trauma has highlighted common themes that should guide the clinician. The hallmark of airway management in these cases is the maintenance of spontaneous ventilation if at all possible, intubation under direct vision to avoid the creation of a false passage, and the avoidance of both intermittent positive pressure ventilation or cricoid pressure during a rapid sequence induction. This situation is distinct from the management of an unanticipated difficult airway. Here, adherence to the DAS 2015 guidelines 6 could actually worsen the situation in this patient population because cricoid pressure, positive pressure ventilation either via a face mask or supraglottic airway device and surgical cricothyroidotomy are all contraindicated.

Consequently, if the primary intubation plan fails, there is only one rescue plan to avoid making the situation worse; surgical tracheostomy. The management of burns patients is broadly similar but with the caveat that the DAS 2015 guidelines 6 apply throughout as the clinician is not faced with the problem of an airway laceration or transection.

Ultimately, when considering all these types of airway trauma, the clinician is faced with a time management issue with a patient falling into one of three groups: No time, some time or adequate time for airway assessment, investigation and intervention. If the patient is in extremis and there is no time for assessment then anaesthetist must manage the case urgently while planning for the worst case scenario: a false passage in blunt, penetrating and blast trauma for example. If the airway appears stable then there is adequate time for assessment, planning and intervention under optimal conditions. Most patients fall somewhere between these two extremes, such that informed decision making is critical for the anaesthetist as the situation can be worsened or stabilized by their subsequent actions. For example, allowing a patient to assume their most comfortable position; be that sitting, lateral or prone may ‘buy enough time’ to undertake nasalendoscopy or a CT 4. Objects that impale the patient should be carefully trimmed so they do not impede subsequent airway interventions 42 89. Finally, location is very important: It could be safer to transfer the patient to theatre to secure the airway, especially if a tracheostomy is required, as there is more space, better lighting and staff more familiar with the intervention.

Human factors are key to the management of a complex anticipated airway problem 90 91. The recently revised Difficult Airway Society Guidelines for the management of an unanticipated difficult airway 6 devote a significant section to these. Leadership, followership, teamwork and situational awareness and communication amongst the team are all vital to ensure the airway is safely secured. A trauma team will often have 10-15 minutes to prepare to receive a patient once they have been activated 86. During this period the anaesthetist should consider the likelihood of airway trauma, the possible investigations and airway interventions required. This includes consideration of what personnel and equipment is needed and specifically who will perform a tracheostomy or surgical cricothyroidotomy if required. The UK-Defence Medical Services have developed the concept of a ‘command huddle’92 where decisions are made by a senior team about further management following the primary survey. A conversation around airway management (if not already taken place) should occur here with a discussion around the airway technique of choice.

The majority of anaesthetists have limited exposure to complex airway trauma and need to develop shared mental models to optimise management techniques and examples of these are included in figures 2 and 3. Our review presents contemporary evidence in management of airway trauma to inform clinical practice. The clinician should also consolidate knowledge through mechanisms such as high fidelity simulation scenarios 93 and by attending workshops specifically for the management of airway trauma.

[Figure 2 Here]

[Figure 3 Here]

**Funding**

There was no funding for this review article

**Declaration of interest**

Ben Morton has received an honorarium for a lecture by Grifols, Inc. This represents no COI for the submitted manuscript.

Simon Mercer, Clint Jones, Matthew Bridge, Edwin Clitheroe and Peter Groom have no conflict of interest to declare

**Authors Contribution**

Substantial contributions to the conception or design of the work **- BM, SJM, PG**

Acquisition of data **- SJM, PG, MB, CJ, EC**

Analysis of data **- BM, SJM, PG, MB, CJ, EC**

Interpretation of data **- BM, SJM, PG, MB, CJ, EC**

Drafting work for important intellectual content **- BM, SJM, PG, CJ**

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