

Observational study of the success rates of intubation and failed intubation airway rescue techniques in 7256 attempted intubations of trauma patients by pre-hospital physicians

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Editor's key points

- There are limited recent data on airway management by physicians in an out-of-hospital setting.
- In this large retrospective series of pre-hospital trauma cases, the initial success rate for tracheal intubation was 99.3%.
- Tracheal intubation was more likely to be successful when performed by a physician with primary training in anaesthesia.
- The need for a surgical airway (0.7%) was lower than in most other reported series.

Background. Effective airway management is a priority in early trauma management. Data on physician pre-hospital tracheal intubation are limited; this study was performed to establish the success rate for tracheal intubation in a physician-led system and examine the management of failed intubation and emergency surgical cricothyroidotomy in pre-hospital trauma patients. Failed intubation rates for anaesthetists and non-anaesthetists were compared.

Methods. A retrospective database review was conducted to identify trauma patients undergoing pre-hospital advanced airway management between September 1991 and December 2012. The success rate of tracheal intubation and the use and success of rescue techniques were established. Success rates of tracheal intubation by individuals and by speciality were recorded.

Results. The doctor-paramedic team attended 28 939 patients; 7256 (25.1%) required advanced airway management. A surgical airway was performed immediately, without attempted laryngoscopy, in 46 patients (0.6%). Tracheal intubation was successful in 7158 patients (99.3%). Rescue surgical airways were performed in 42 patients, seven had successful insertion of supraglottic devices, and two patients had supraglottic device insertion and a surgical airway. One patient breathed spontaneously with bag-valve-mask support during transfer. All rescue techniques were successful. Non-anaesthetists performed 4394 intubations and failed to intubate in 41 cases (0.9%); anaesthetists performed 2587 intubations and failed in 11 (0.4%) ($P=0.02$).

Conclusions. This is the largest series of physician pre-hospital tracheal intubation; the success rate of 99.3% is consistent with other reported data. All rescue airways were successful. Non-anaesthetists were twice as likely to have to perform a rescue airway intervention than anaesthetists. Surgical airway rates reported here (0.7%) are lower than most other physician-led series (median 3.1%, range 0.1–7.7%).

Keywords: airway management; complications, intubation; intubation; pre-hospital emergency care

Immediate and effective airway management is a priority in the resuscitation of critically injured patients. There are data to suggest that, in some Emergency Medical Service (EMS) systems, paramedic airway management performed by the ambulance service does not appear to meet the needs of seriously injured patients with airway compromise.^{1–5} Some pre-hospital services, particularly in Europe, provide physicians to manage critically ill patients. Data on physician pre-hospital intubation are limited, despite the fact that this intervention has been carried out on a daily basis in EMS systems worldwide for many years.⁶ This study reports a retrospective observational database review of physician airway management in an

urban pre-hospital trauma service, which dispatches a physician-paramedic team to major trauma patients. The study was conducted in our physician-led pre-hospital system to establish success rates of intubation, the frequency and management of failed intubation in the pre-hospital trauma patient, and the rates of failed intubation between the two main groups of physician providers within the system (anaesthetists and non-anaesthetists).

Intubation success rates and an effective failed intubation rescue plan are both quality markers of an EMS system conducting rapid sequence induction.^{7,8} The study was designed to use intubation success rates as a quality indicator to establish

how the care provided by this doctor-paramedic team compares with existing physician data.

Methods

A retrospective database review of all patients attended by the pre-hospital physician-led trauma service between September 1991 and December 2012 was conducted to identify those patients undergoing advanced airway management in the pre-hospital phase. Drownings, hangings, traumatic asphyxia, and inhalation injuries are attended and were included. Data collected included the number of missions carried out, the number of patients requiring advanced airway interventions (intubation, supraglottic airway insertion, or surgical airway), the number of successful intubations, and the success and type of rescue techniques. The speciality and individual intubation success rates of the doctors were also recorded. For the purposes of the study, doctors were broadly categorized as anaesthetists and non-anaesthetists. An anaesthetist was defined as a pre-hospital physician with anaesthesia as their primary speciality and a postgraduate diploma in anaesthetics; all are required to have a minimum of 6 months experience in emergency medicine. A non-anaesthetist was a pre-hospital physician with a postgraduate diploma in any other primary speciality. The vast majority of non-anaesthetists in this study were emergency physicians with a minimum of 6 months in-hospital anaesthetic experience. All doctors in the service are at least 5 yr post-qualification. Further in-service training is provided in a 4–6 week induction period under the guidance and supervision of dedicated pre-hospital care consultants and weekly case review, audit, and clinical governance meetings.

Data analysis was carried out using simple descriptive statistics with Microsoft Excel™ 2011 and GraphPad™. The χ^2 test was used to calculate the statistical significance of proportions; statistical significance was set at $P < 0.05$. No additional data were collected for this study and no additional interventions carried out. The project met local criteria for, and was registered as, a service evaluation project.

In order to describe the system in which this study was based, the 'Fixed system variables' for uniform reporting of data from advanced airway management in the field, identified by an international expert consensus group, are described.⁹ The study was conducted in an urban, physician-led, pre-hospital trauma service, serving a daytime population of up to 10 million in an area of ~5000 km². A doctor-paramedic team is delivered by helicopter during daylight hours and by fast response car at night. Flight paramedics in the ambulance control room dispatch the service only to trauma patients and specific dispatch criteria target patients with severe injury. A standard land ambulance is always dispatched in addition to the physician-paramedic team. On average, five to six trauma patients are attended per day. The attending pre-hospital physician records standard patient data on a Microsoft ACCESS™ database shortly after missions.

Pre-hospital anaesthesia is carried out in line with UK recommendations⁷ and according to local standard operating procedures (SOPs), which are deliberately straightforward,

aiming to minimize choice in order to achieve high intubation success rates. The anaesthetic agents used were standardized in 1996 and the use of etomidate for induction of anaesthesia and succinylcholine for neuromuscular block persisted until 2012. In 2012, after recognition that physiological disturbance might be better avoided in some patient groups by using a technique closer to that used in hospital emergency departments, the current SOP was adopted. This includes the use of an opioid agent (fentanyl), ketamine for induction and rocuronium for neuromuscular block.

In 2005, supraglottic airway devices were introduced into clinical practice as an alternative to emergency cricothyroidotomy for the management of failed intubation. The Proseal LMA™ (Intavent Direct, UK) was initially chosen for the potential ability to ventilate at higher inflation pressures and the presence of a gastric drainage channel to minimize aspiration. This was changed to the I-Gel™ (Intersurgical, UK) for the ease of insertion in 2010. The local ambulance service also uses this device. Surgical airways are performed either as primary airway management in certain circumstances or as a rescue technique after failed intubation. The decision of when to use a surgical airway and when to use a supraglottic airway device for rescue of failed intubation is not clearly defined in the SOP and is a clinical decision made by the attending physician. Emphasis in training is on rapid, effective airway control.

Pre-induction checklists, regular low-fidelity 'moulage' practice, and pre-prepared anaesthetic drugs were in use by 2006.

Results

Over the study period, the doctor-paramedic team attended 28 939 trauma patients (Table 1). Of these, 7256 (25.1%) required advanced airway management. Forty-six patients (0.6%) had an immediate surgical airway performed without any attempted laryngoscopy. The remaining 7210 patients had attempted intubation, which was successful in 7158

Table 1 Mechanism or type of injury in patients who received a surgical airway. RTC, road traffic collision

Mechanism of injury	Number of patients [n (%)]	Primary procedure (n)	Rescue procedure (n)
Burns	21 (23.3)	9	12
RTC	28 (31.1)	17	11
Hanging	8 (8.9)	2	6
Head/facial injuries	8 (8.9)	1	7
Fall from height	6 (6.7)	3	3
Fall under train	3 (3.3)	3	0
Multiple injuries	9 (10.0)	6	3
Penetrating	7 (7.8)	5	2
Total	90 (100)	46	44

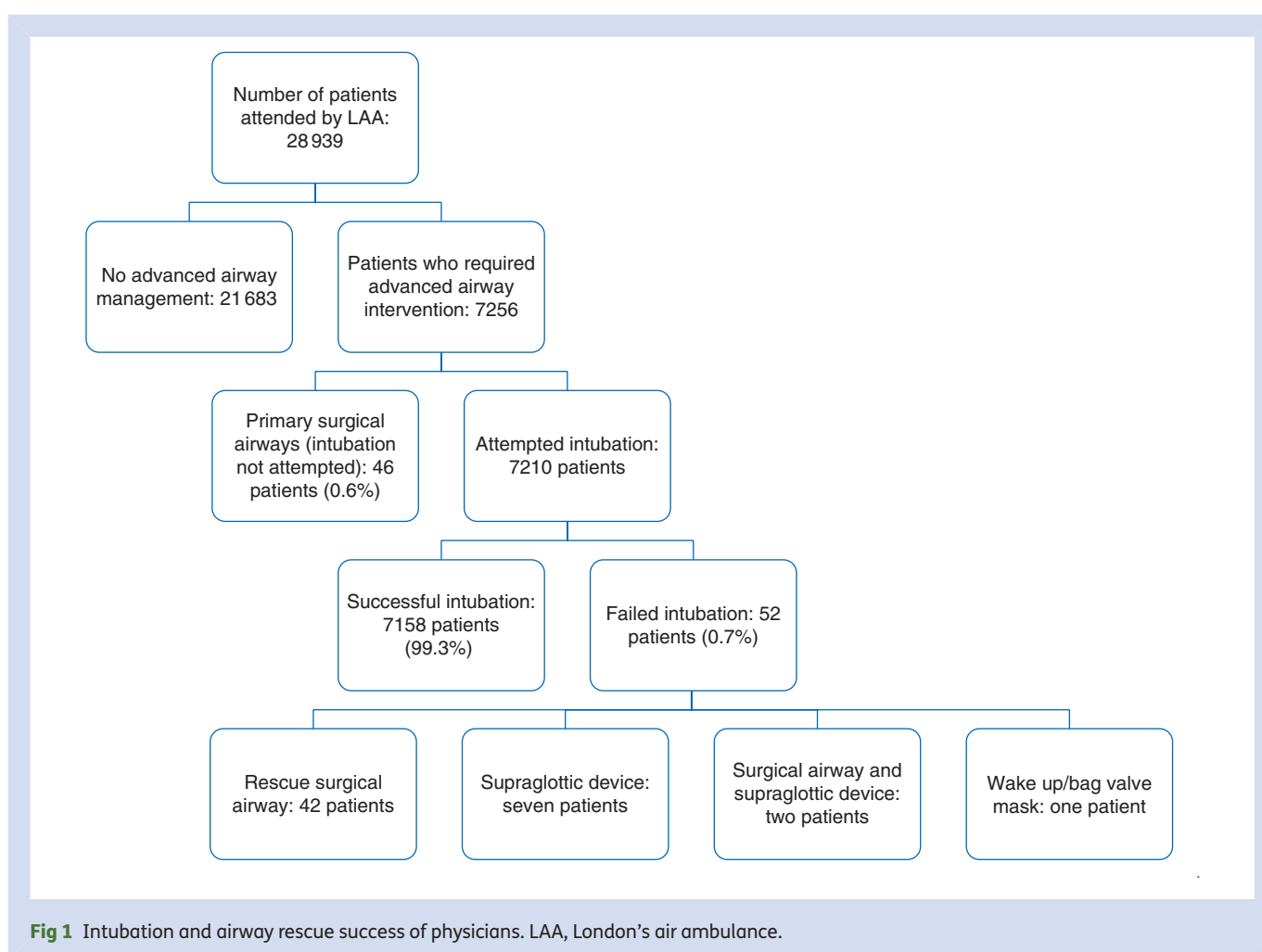
(99.3%). Fifty-two patients (0.7%) could not be intubated. Rescue surgical airways were performed in 42 patients, seven patients had successful insertion of a supraglottic device, and in two patients, a supraglottic device was initially inserted but a surgical airway was performed before transfer to hospital. One patient was allowed to spontaneously breathe with bag-valve-mask support during transfer to hospital (Fig. 1). All surgical airways (both primary and rescue) were successful.

The most common mechanism of injury resulting in a surgical airway was road traffic collision (RTC); 29 patients required this intervention after RTCs. Seventeen of these 29 patients (63%) had a primary surgical airway; of these, nine patients were trapped. Two other patients who were trapped after falling under a train also required primary surgical airways. Seventeen patients with severe injuries, usually to the head and neck, required surgical airways. Overall, there were 18 survivors (20%) in the surgical airway group; outcome data were unavailable for one patient. Ten patients who underwent a primary surgical airway survived (22%) compared with eight patients with a rescue surgical airway (19%) ($P=0.797$). Twenty-nine patients were in traumatic cardiac arrest at the time of having a surgical airway; all died.

Data identifying the speciality of the intubating doctor were available for 7033 attempted intubations. Non-anaesthetists carried out 4394 attempted intubations and failed to intubate in 41 cases (0.9%), whereas anaesthetists attempted to intubate 2587 patients and failed in 11 (0.4%) ($P=0.02$). A new SOP was introduced in May 2012 and no failed intubations have occurred since. Between the introduction of the new SOP and the end of the study period, 314 intubations were performed. The difference in success rate before and after introduction was not statistically significant ($P=0.17$). Forty-one out of 186 doctors (22%) had at least one failed intubation; 145 (78%) had no failed intubations. Among the 22% with documented failed intubation, the mean failure rate was 3.3% compared with 0.7% for the whole cohort. Six doctors had failure rates of $>5\%$ and one had a failure rate of $>10\%$ (although this was only one failed intubation in eight intubation attempts, 12.5%).

Discussion

To our knowledge, this study reports the largest series of physician pre-hospital intubation success to date⁶ and considerably increases the available physician data. The reported success rate (99.3%) is in keeping with other smaller published



series where the pooled median intubation success rate was 99.1%.⁶ The use of surgical and supraglottic airways was, when attempted, always successful. The introduction of supraglottic airways has resulted in a proportion of rescue interventions carried out without surgical airway. The Airtraq™ video laryngoscope (Prodol Medical, Spain) has been selected for introduction into the service in the 'can't intubate, can ventilate' scenario. This device has been selected on the basis of integral long battery shelf-life and size, despite reported difficulties in patients with airway contamination.¹⁰

Non-anaesthetists had a higher rate of failed intubation than anaesthetists and were twice as likely to have to perform a rescue airway intervention and this difference was statistically significant. A limitation of this observation is that there was no attempt to examine whether there were significant differences between the patient group intubated by anaesthetists and non-anaesthetists, but there is no reason to suspect that there would be a difference. The model of emergency physicians and anaesthetists in our system fits the model of 'competent' and 'expert' intubators recently defined by Breckwoldt and colleagues.¹¹ This model defines 'competent' and 'expert' by the number of intubations carried out in routine practice by different physicians and recognizes that those with greater intubation experience have higher success rates. This observed difference might be useful in targeting training and in the development of SOPs. Since the rate of failed intubation is low, it is not possible to assess the influence of new SOPs on failed intubation. The zero failure rate since this latest SOP introduction is not statistically different from the previous failure rate. The rate of intubation failure between individuals is interesting. The majority have no failures, but among the whole doctor population, failure rates are very variable (0–12.5%). Early identification of 'outliers' may be useful to target training through early focused teaching and assessment. Adherence to protocols may also benefit physicians in training and potentially reduce the incidence of failed tracheal intubation.

Emergency cricothyroidotomy, although infrequently performed, is an essential skill in the management of the difficult airway. Studies reporting on real patients are rare and despite the fact that <100 cases are reported here, this is one of the largest series described to date. In this study, all surgical airways were successful in establishing an adequate airway for oxygenation and ventilation. As expected, a significant proportion of surgical airways were performed on trapped patients, those with severe burns, and those with significant head and neck injuries. Most were severely injured and this is reflected in the very high mortality rate. In this series, there were no survivors among the group of patients who were in established traumatic cardiac arrest and required surgical airways; this finding is not unexpected since the mortality from traumatic cardiac arrest is always high.¹²

The rate of surgical airway reported here is lower than that reported in most other smaller series (Table 2) where pre-hospital physicians performed surgical cricothyroidotomy in 3.1% of cases (range 0.1–7.7%)^{13–16} and non-physicians performed them in 7.95% of patients (median, range 0.5–

18.2%).^{17–26} The difference in skill mix and experience that exists between pre-hospital providers is likely to influence the rate of failed intubations and cricothyroidotomy. Those services in which neuromuscular blocking agents are not used in advanced airway management protocols may be more likely to have fewer successful intubations and more surgical airways.^{6,22} In this study, all surgical airways were successful and performed using a standard surgical technique; a 'successful' procedure is defined as correct placement of a tracheal tube in the trachea followed by adequate ventilation. The majority of studies of physician-led pre-hospital services also report success rates of 100%. In almost all the patients in these studies, a standard surgical technique for cricothyroidotomy was used.^{13,16} Two studies reported limited success with needle cricothyroidotomy. In one study of 1106 patients undergoing advanced airway management, needle cricothyroidotomy was performed in one patient after failed intubation.¹⁵ The second study, a survey of UK pre-hospital physicians in 2008, reported use of needle cricothyroidotomy in 17 patients; 11 of these cases required conversion to another technique, including surgical cricothyroidotomy.²⁷ There are other reports of success with a surgical technique after failed needle or cannula cricothyroidotomy.²⁸ Another physician-led service reported a lower success rate of 90% when using either a standard surgical technique or commercially available kits (Seldinger method). The standard surgical technique was found to be both quicker and more successful.²⁹ The increased success rate with a standard surgical technique over a needle approach was confirmed in a recent meta-analysis where surgical cricothyroidotomy success rates were 90.5% compared with 65.8% for needle cricothyroidotomy.³ Studies comparing the different commercial cricothyroidotomy kits with a surgical technique also conclude that a surgical technique is likely to achieve a definitive airway in a faster time, with fewer complications.^{30–32}

The limited evidence available suggests that surgical cricothyroidotomy is more successful than needle or commercial kit techniques and should be the technique of choice when faced with a 'can't intubate, can't ventilate' scenario. The delay in obtaining a definitive airway, when a needle or cannula technique is initially attempted but fails, could well translate into an increase in morbidity and mortality.³³ All personnel who may be required to perform an emergency cricothyroidotomy should be fully trained and equipment readily available.

Unfortunately, high cricothyroidotomy success rates do not necessarily translate into high survival rates. The available literature suggests an overall survival rate of 26.5%,¹⁶ although the heterogeneity in case mix, injury severity scores, and level of emergency service personnel make it difficult to interpret survival rates with any confidence. As surgical airways are commonly used as a last resort for severely injured patients where conventional airway management has failed, it is unsurprising that the overall survival is low. In total, 20% of patients in this study survived to leave hospital. The survival rates in the primary and rescue groups were similar.

This study has demonstrated a high intubation success rate and 100% rescue success rate in a physician-led trauma

Table 2 Pre-hospital cricothyroidotomy rates. NS, not stated; R, retrospective; P, prospective

Authors	Study design	Healthcare provider	Surgical airway [n (%)]	Success rate (%)	Complication rate (%)	Survivors [n (%)]
Miklus, <i>J Trauma</i> , 1989 ¹³	R	Physicians	20 (3.8)	100	0	8 (40)
Spaite, <i>Ann Emerg Med</i> , 1990 ³⁸	R	Paramedics	16 (unknown)	88	31	3 (19)
Cook, <i>J Air Med Transp</i> , 1991 ¹⁷	R	Paramedics/nurses	68 (2)	100	4.4	21 (31)
Nugent, <i>Ann Emerg Med</i> , 1991 ¹⁸	R	Nurses	55 (18.2)	96	15	15 (27)
Xeropotamos, <i>Injury</i> , 1993 ³⁹	R	Physicians	11 (7.7)	100	0	4 (37)
Boyle, <i>J Emerg Med</i> , 1993 ¹⁹	R	Nurses	69 (10.6)	98.5	9	5 (7)
Jacobson, <i>J Trauma</i> , 1996 ⁴⁰	R	Paramedics	50 (9.8)	94	4	19 (38)
Fortune, <i>J Trauma</i> , 1997 ²³	R	Paramedics	56 (15)	88	14	15 (27)
Gerich, <i>J Trauma</i> , 1998 ¹⁴	P	Physicians	8 (2.4)	100	0	1 (12.5)
Robinson, <i>Air Med J</i> , 2001 ²⁰	R	Paramedics/nurses	8 (0.5)	62.5	NS	NS
Bair, <i>J Emerg Med</i> , 2003 ²¹	R	Nurses	22 (10.9)	100	54.5	NS
Marcolini, <i>Prehosp Emerg Care</i> , 2004 ⁴¹	R	Paramedics	68	NS	NS	8 (12)
Timmermann, <i>Resuscitation</i> , 2006 ¹⁵	P	Physicians	1 (0.1)	100	0	NS
Mcintosh, <i>J Trauma</i> , 2008 ²⁴	R	Paramedics/nurses	17 (2.4)	100	12	7 (41)
Germann, <i>Prehosp Emerg Care</i> , 2009 ²⁵	R	Paramedics/nurses	6 (1.6)	100	NS	NS
Bulger, <i>J Emerg Med</i> , 2002 ⁴²	R	Paramedics	Needle: 30 (1)	NS	NS	37
Leibovici, <i>Am J Emerg Med</i> , 1997 ²⁹	R	Physicians	Seldinger: 13; surgical: 16	90	Seldinger: 23; surgical: 0	45
Warner, <i>J Emerg Med</i> , 2009 ⁴³	P	Paramedics	Needle: 4 (3); surgical: 11 (8.5)	Needle: 25; surgical: 90	18	NS
Nakayama, <i>Ann Surg</i> , 1990 ⁴⁴	R	NS	2 (22); all needle	0	100	0

service. This considerably increases the available evidence in this area of pre-hospital emergency medicine and suggests that high-quality anaesthesia can be delivered before arrival in hospital. The study also suggests higher success rates in anaesthetists than emergency physicians and also documents considerable variation in the success rates of individual doctors. Algorithms have standardized advanced airway management³⁴ and reduced failed intubation rates, both in the pre-hospital setting³⁵ and in the emergency department.³⁶ Adherence to specific protocols and regular assessment and moulage are likely to be of benefit to physicians in training. Emergency cricothyroidotomy is rarely performed but potentially lifesaving, and the high success rate demonstrated in this paper supports the evidence, which suggests a simple surgical approach is a reliable technique. This study reports intubation success and the management of intubation failure. Both are quality indicators of pre-hospital airway management, but other measures of quality including physiological derangement are also very important to outcome³⁷ and have not been described in this study.

Authors' contributions

D.L.: conceived the study, collected the data, and is co-author of first and subsequent drafts. K.C.: co-author of first and subsequent drafts. A.W.: reviewed and constructively criticized the manuscript. G.D.: reviewed and constructively criticized the manuscript.

Declaration of interest

None declared.

References

- 1 NCEPOD. Trauma: Who Cares? Report of the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) www.ncepod.org.uk/2007report2/Downloads/SIP_report.pdf (accessed 26 June 2014)
- 2 Cobas MA, La Peña De MA, Manning R, Candiotti K, Varon AJ. Prehospital intubations and mortality: a level 1 trauma center perspective. *Anesth Analg* 2009; **109**: 489–93
- 3 Hubble MW, Wilfong DA, Brown LH, Hertelendy A, Benner RW. A meta-analysis of prehospital airway control techniques part II: alternative airway devices and cricothyrotomy success rates. *Prehosp Emerg Care* 2010; **14**: 515–30
- 4 Davis DP, Hoyt DB, Ochs M, et al. The effect of paramedic rapid sequence intubation on outcome in patients with severe traumatic brain injury. *J Trauma* 2003; **54**: 444–53
- 5 Sise MJ, Shackford SR, Sise CB, et al. Early intubation in the management of trauma patients: indications and outcomes in 1,000 consecutive patients. *J Trauma* 2009; **66**: 32–40
- 6 Lossius HM, Røislien J, Lockey DJ. Patient safety in pre-hospital emergency tracheal intubation: a comprehensive meta-analysis of the intubation success rates of EMS providers. *Crit Care* 2012; **16**: R24
- 7 The Association of Anaesthetists of Great Britain and Ireland. *Guidelines for Pre-hospital Anaesthesia*, 2009. Available from http://www.aagbi.org/sites/default/files/prehospital_glossy09.pdf (accessed 15 October 2012)

- 8 Wang HE, Davis DP, O'Connor RE, Domeier RM. Drug-assisted intubation in the prehospital setting (resource document to NAEMSP position statement). *Prehosp Emerg Care* 2006; **10**: 261–71
- 9 Sollid SJM, Heltne JK, Søreide E, Lossius HM. Pre-hospital advanced airway management by anaesthesiologists: is there still room for improvement? *Scand J Trauma Resusc Emerg Med* 2008; **16**: 2
- 10 Trimmel H, Kreutziger J, Fertsak G, Fitzka R, Dittich M, Voelckel WG. Use of the Airtraq laryngoscope for emergency intubation in the prehospital setting: a randomized control trial. *Crit Care Med* 2011; **39**: 489–93
- 11 Breckwoldt J, Klemstein S, Brunne B, Schnitzer L, Arntz H-R, Mochmann H-C. Expertise in prehospital endotracheal intubation by emergency medicine physicians—comparing 'proficient performers' and 'experts'. *Resuscitation* 2012; **83**: 434–9
- 12 Lockey D, Crewdson K, Davies G. Traumatic cardiac arrest: who are the survivors? *Ann Emerg Med* 2006; **48**: 240–4
- 13 Miklus RMR, Elliott CC, Snow NN. Surgical cricothyrotomy in the field: experience of a helicopter transport team. *J Trauma* 1989; **29**: 506–8
- 14 Gerich TGT, Schmidt UU, Hubrich VV, Lobenhoffer HPH, Tscherne HH. Prehospital airway management in the acutely injured patient: the role of surgical cricothyrotomy revisited. *J Trauma* 1998; **45**: 312–4
- 15 Timmermann A, Eich C, Russo SG, et al. Prehospital airway management: a prospective evaluation of anaesthesia trained emergency physicians. *Resuscitation* 2006; **70**: 179–85
- 16 Xeropotamos NS, Coats TJ, Wilson AW. Prehospital surgical airway management: 1 year's experience from the Helicopter Emergency Medical Service. *Injury* 2013; **24**: 222–4
- 17 Cook S, Dawson R, Falcone RE. Prehospital cricothyrotomy in air medical transport: outcome. *J Air Med Transp* 1991; **10**: 7–9, 12
- 18 Nugent WL, Rhee KJ, Wisner DH. Can nurses perform surgical cricothyrotomy with acceptable success and complication rates? *Ann Emerg Med* 1991; **20**: 367–70
- 19 Boyle MF, Hatton D, Sheets C. Surgical cricothyrotomy performed by air ambulance flight nurses: a 5-year experience. *J Emerg Med* 1993; **11**: 41–5
- 20 Robinson KJ, Katz R, Jacobs LM. A 12-year experience with prehospital cricothyrotomies. *Air Med J* 2001; **20**: 27–30
- 21 Bair AE, Panacek EA, Wisner DH, Bales R, Sakles JC. Cricothyrotomy: a 5-year experience at one institution. *J Emerg Med* 2003; **24**: 151–6
- 22 Jacobson LE, Gomez GA, Sobieray RJ, Rodman GH, Solotkin KC, Misinski ME. Surgical cricothyroidotomy in trauma patients: analysis of its use by paramedics in the field. *J Trauma* 2013; **41**: 15–20
- 23 Fortune JB, Judkins DG, Scanzaroli D, McLeod KB, Johnson SB. Efficacy of prehospital surgical cricothyrotomy in trauma patients. *J Trauma* 1997; **42**: 832–8
- 24 McIntosh SE, Swanson ER, Barton ED. Cricothyrotomy in air medical transport. *J Trauma* 2008; **64**: 1543–7
- 25 Germann CA, Baumann MR, Kendall KM, Strout TD, McGraw K. Performance of endotracheal intubation and rescue techniques by emergency services personnel in an air medical service. *Prehosp Emerg Care* 2009; **13**: 44–9
- 26 Warner KJ, Sharar SR, Copass MK, Bulger EM. Prehospital management of the difficult airway: a prospective cohort study. *J Emerg Med* 2011; **36**: 257–65
- 27 Price RJ, Laird C. A survey of surgical airway experiences and equipment among immediate care doctors. *Emerg Med J* 2009; **26**: 438–41
- 28 Peterson GN, Domino KB, Caplan RA, Posner KL, Lee LA, Cheney FW. Management of the difficult airway: a closed claims analysis. *Anesthesiology* 2005; **103**: 33–9
- 29 Leibovici F, Gofrit S, Blumenfeld S. Prehospital cricothyroidotomy by physicians. *Am J Emerg Med* 1997; **15**: 3
- 30 Craven RM, Vanner RG. Ventilation of a model lung using various cricothyrotomy devices. *Anaesthesia* 2004; **59**: 595–9
- 31 Eisenburger PP, Laczika KK, List MM, et al. Comparison of conventional surgical versus Seldinger technique emergency cricothyrotomy performed by inexperienced clinicians. *Anesthesiology* 2000; **92**: 687–90
- 32 Dimitriadis JC, Paoloni R. Emergency cricothyroidotomy: a randomised crossover study of four methods. *Anaesthesia* 2008; **63**: 1204–8
- 33 Crewdson K, Lockey DJ. Needle, knife, or device—which choice in an airway crisis? *Scand J Trauma Resusc Emerg Med* 2013; **21**: 1
- 34 Henderson JJJ, Popat MTM, Latta IPI, Pearce ACA. Difficult Airway Society guidelines for management of the unanticipated difficult intubation. *Anaesthesia* 2004; **59**: 675–94
- 35 Combes X, Jabre P, Jbeili C, et al. Prehospital standardization of medical airway management: incidence and risk factors of difficult airway. *Acad Emerg Med* 2006; **13**: 828–34
- 36 Stephens CT, Kahntroff S, Dutton RP. The success of emergency endotracheal intubation in trauma patients: a 10-year experience at a major adult trauma referral center. *Anesth Analg* 2009; **109**: 866–72
- 37 Davis DP, Dunford JV, Poste JC, et al. The impact of hypoxia and hyperventilation on outcome after paramedic rapid sequence intubation of severely head-injured patients. *J Trauma* 2004; **57**: 1–10
- 38 Spaite DW, Joseph M. Prehospital cricothyrotomy: an investigation of indications, technique, complications, and patient outcome. *Ann Emerg Med* 1990; **19**: 279–85
- 39 Xeropotamos NS, Coats TJ, Wilson AW. Prehospital surgical airway management: 1 year's experience from the Helicopter Emergency Medical Service. *Injury* 1993; **24**: 222–4
- 40 Jacobson LE, Gomez GA, Sobieray RJ, Rodman GH, Solotkin KC, Misinski ME. Surgical cricothyroidotomy in trauma patients: analysis of its use by paramedics in the field. *J Trauma, Injury, Infect, Critic Care* 1996; **41**: 15–20
- 41 Marcolini EG, Burton JH, Bradshaw JR, Baumann MR. A standing-order protocol for cricothyrotomy in prehospital emergency patients. *Prehosp Emerg Care* 2004; **8**: 23–8
- 42 Bulger EM, Copass MK, Maier RV, Larsen J, Knowles J, Jurkovich GJ. An analysis of advanced prehospital airway management. *J Emerg Med* 2002; **23**: 183–9
- 43 Warner KJ, Sharar SR, Copass MK, Bulger EM. Prehospital management of the difficult airway: a prospective cohort study. *J Emerg Med* 2009; **36**: 257–65
- 44 Nakayama DK, Gardner MJ, Rowe MI. Emergency endotracheal intubation in pediatric trauma. *Ann Surg* 1990; **211**: 218–23

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