

Pre-hospital Anaesthesia

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Abstract

This review presents the history of Pre-hospital anaesthesia, its evidence base, required training and examines current arguments focusing on best practice such as who should undertake the procedure and how identifying appropriate patients, utilizing new techniques and drugs may benefit the Pre-hospital practitioner in optimum delivery of this important procedure.

Introduction

Pre-hospital anaesthesia is used to rapidly secure and protect the airway, prevent secondary brain injury, for humanitarian reasons and to facilitate safe transfer when access to the patient may be less than ideal. Traditionally, the airway is secured by a technique known as Rapid Sequence Induction and Intubation (RSII). Securing the airway is second in importance only to the control of catastrophic haemorrhage, but pre-hospital anaesthesia is more than securing the airway, and intubation merely the first step. Once the airway is secured, supporting physiology, preventing secondary injury and safe transfer to an appropriate centre is the goal in the pre-hospital phase.

Definition and History of Rapid Sequence Induction/Intubation

RSII is defined by Walls in the Manual of Emergency Airway Management 3rd Edition (Lippincott Williams & Wilkins) as *"the administration, after preoxygenation, of a potent induction agent followed immediately by a rapidly acting neuromuscular blocking agent to induce unconsciousness and motor paralysis for tracheal intubation"*

The preoxygenation phase permits a period of apnoea to occur between administering drugs and intubating the trachea. RSII is used on the predicated assumption that the patient has a full stomach and may be at risk of pulmonary aspiration of gastric contents. This has long been recognized as a risk during anaesthesia. In 1950, the Association of Anaesthetists of Great Britain and Ireland (AAGBI) investigated deaths associated with anaesthesia and discovered 43 deaths caused by aspiration. Six years on, another 110 deaths due to aspiration of gastric contents were reported.

In 1961, Brian Sellick first described a manoeuvre attempting to control and minimize regurgitation of gastric contents before intubation by compressing the cricoid cartilage against the bodies of the cervical vertebrae. Prior to this, anaesthesia was induced in an upright position to provide airway protection, but debate still reigns regarding cricoid pressure [1].

A 'classical' RSII incorporates Sodium Thiopentone (STP) as the induction agent and Suxamethonium for neuromuscular blockade (NMB) followed swiftly by tracheal intubation. Tracheal intubation was not routine until the 1940s when STP was used in WWII for military anaesthesia. Suxamethonium was first synthesised in 1949, Ketamine in 1961, etomidate in 1964 and

Propofol in 1980. Despite their age, STP and Suxamethonium remain the most widely used agents. What is now apparent however, is that there is no universal regime [2], and that RSII is evolving slowly as new drugs, equipment and knowledge emerge. Several induction agents as well as alternatives to Suxamethonium are used by both anaesthetists and non-anaesthetists. These include using the long acting non-depolarizing neuromuscular blocking agent Rocuronium, instead of Suxamethonium, as the ability now exists to rapidly reverse Rocuronium-induced paralysis with Sugammadex.

Who should perform pre-hospital Rapid Sequence Induction/Intubation (PHRSII)?

PHRSII brings with it its own unique challenges. It is an austere environment, often with little back up, with the capacity for failure higher than in hospital. These factors all undoubtedly contribute to why many studies looking for any benefit of pre-hospital intubation have been inconclusive. Note the deliberate use of the term *pre-hospital intubation*. Many of the studies involved did not use NMB, used inadequate or no clinical monitoring, personnel often had short and poor training, had differing skill sets, and poor study design and methods [3]. The majority of pre-hospital intubations were not RSII's. The Joint Royal Colleges Ambulance Liaison Committee have recently stated that UK paramedics should no longer be routinely trained in intubation [4], as evidence of benefit to patients intubated without drugs is lacking. London Ambulance Service have recently ceased training paramedics in endotracheal intubation (June 2010). A criticism often leveled by hospital practitioners regarding interventions undertaken on scene relates to the extra time taken to undertake those procedures, thereby prolonging the on scene time. Critical care is a process, not a place, and the patient requires an intervention when *they* require it, not when they have been transported to hospital. Interventions such as RSII, blood transfusion and large bore central access are undertaken routinely in the emergency department (ED) for conditions such as traumatic brain injury (TBI) and polytrauma, and are seen as minimum standards of care. Hypoxia, hypotension and hypercapnia all increase mortality and morbidity in TBI. PHRSII allows control of oxygenation and ventilation early and safely in the pre-hospital phase.

There is evidence that a well organised physician anaesthetist staffed pre-hospital organisation can deliver anaesthesia in the pre-hospital phase as safely as in hospital [5-7]. The data on other groups is conflicting. This may be in part due to training and skill levels but also due to the drug combinations with midazolam and etomidate all reported as agents used to achieve a drug assisted intubation but without muscle relaxants [8-11].

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The two largest UK studies of ED RSII where ED staff were compared to anaesthetists showed that anaesthetists achieved significantly better views at laryngoscopy and more first time intubations [12-13]. A study of RSII performed by non-anaesthetists (critical care and ED staff) reported a significantly higher incidence of multiple attempts and unsuccessful intubation by the initial operator [14]. This finding is important as a large US study found that the incidence of complications increases significantly when more than one attempt at intubation is required [15]. Graham's paper [13] reported almost three times as many oesophageal intubations (17 vs. 6), twice as many episodes of severe hypotension (17 vs. 8) and twice as many (6 vs. 3) endobronchial intubations during RSII by ED staff. These numbers were not assessed for statistical significance and are small (in a series of 735 RSII) but may represent clinically significant harm. Reid's study [14] showed a significantly higher incidence of multiple attempts and unsuccessful intubation when the initial intubator was not an anaesthetist; however overall (albeit self-reported) complications were similar. Similarly the Stevenson paper [12] reported overall comparable complication rates for ED vs. anaesthetic RSII. The choice of agent used is worthy of comment in that most anaesthetists choose to use propofol or thiopentone. One might speculate that the episodes of hypotension requiring treatment might have been significantly reduced for anaesthetists had they used etomidate (ED 72% Etomidate vs. anaes 19%). This is possibly because the majority of anaesthetists were junior trainees with little or no experience of using etomidate, whereas the majority of ED physicians were consultants. Despite using drugs more likely to produce hypotension, the anaesthetists had no more episodes of hypotension than the ED staff. Familiarity with the side effects and appropriate doses of induction agents, and the ability to minimize and manage adverse effects is as important as the ability to get the tube in with the best view.

The AAGBI produced a set of guidelines for PHRSII in 2009 [16]. A panel concluded that practitioners "should have the same level of training and competence that would enable them to perform RSII unsupervised in the emergency department". This should include training through the acute care common stem (or equivalent). An expert panel in 2007 on behalf of The National Confidential Enquiry into Patient Outcome and Death (NCEPOD) produced the report "Trauma who cares" [17] and concluded: "Airway management in trauma patients is often challenging. The pre-hospital response for these patients should include someone with the skill to secure the airway, (including the use of rapid sequence intubation), and maintain adequate ventilation" and furthermore "If pre-hospital intubation is to be part of the pre-hospital trauma management plan, it needs to be in the context of a physician based pre-hospital care system". Once a satisfactory level of competency has been attained, this needs to be maintained, with at least one drug assisted intubation per month currently thought to be the absolute minimum required to maintain competency.

These recent recommendations effectively limit the provision of PHRSII to those who regularly undertake RSII in the course of their job such as anaesthetists or occasionally emergency physicians and rarely to others who have the flexibility to attain the competencies and maintain regular sessions undertaking RSII in a supervised environment.

Indications for PHRSII

After arrival in the ED, RSII will usually be carried out early to secure the airway, to improve physiological variables, for

humanitarian reasons, and to facilitate safe further investigation (e.g. CT). To carry this argument forward, should the patient require the intervention during the patient journey but in the pre-hospital phase, then there is logic to carrying out RSII in the pre-hospital environment if it can be done safely. The evidence above supports this, when undertaken by a well trained senior team under optimized conditions. However, the evidence to date does not support any survival benefit over non-RSII managed patients and if performed by those lacking experience or using sub-optimal techniques then this may be harmful. It may be reasonable to be more conservative with pre-hospital RSII than in the Emergency department.

Indications for PHRSII include:

- **Airway problems** that cannot be reliably managed by simple manoeuvres e.g. severe facial injury
- **Respiratory insufficiency** ($SpO_2 < 92\%$) despite 15L/min O_2 or impending respiratory collapse due to exhaustion or pathology
- **GCS rapidly falling** or < 9 .
- **Patients at risk of deterioration** when access is difficult during transfer to definitive care e.g. facial burns
- **Patients requiring analgesia and/or sedation** prior to transfer to hospital because they present a danger to themselves or attending staff or for humanitarian reasons e.g. provide complete pain relief without respiratory depression.

Using published and accepted guidelines, any patients in pain or at risk of deterioration should be considered for PHRSII. This effectively means any patient with major illness or injury. Clearly not all patients can or should receive anaesthesia and it is probably more helpful to think in terms of contraindications to the procedure;

- **Lack of a suitably trained team**
- **Conditions likely to make intubation difficult or impossible** where other techniques only available in hospital may be required e.g. facial deformity, epiglottitis, lack of difficulty airway equipment

There is currently no randomized controlled data showing clear benefit in mortality or morbidity following pre-hospital intubation. The only randomized controlled trial of pre-hospital intubation performed so far involved paramedics intubating children without drugs [18] and in addition to the lack of doctors and drugs (i.e. not PHRSII), the study had major flaws. There have been several retrospective studies conducted in this area, and overall these have not been conclusive. Some of the studies suggest survival advantage [19-20]. Others showed no improvement in neurological outcome or mortality [21] or even appeared to show an adverse outcome from pre-hospital intubation [22-23]. A recent review in the British Journal of Anaesthesia [24] reviewed the value of pre-hospital tracheal intubation in patients with traumatic brain injury and concluded there was no evidence to support pre-hospital intubation. Unfortunately this detailed systematic review made no attempt to distinguish those patients given drugs (or not) to facilitate intubation nor operator skill level. In the majority of cases the drugs used were not stated and in other studies paramedics were taught to perform intubation with six or eight hours training. Comparing anaesthesia delivered by consultant anaesthetists (to standard guidelines) in the pre-hospital environment is very different to intubation by a paramedic with six hours training without the use of drugs.

Induction Agent	General Info	Dose	Advantages for PHRSII	Disadvantages for PHRSII
Sodium Thiopentone (STP)	<p>Packaged as a yellow powder in a "multi-dose" glass bottle that requires reconstitution with 20mls of water to make up a 25mg/ml solution. Stable for days in this made up state.</p> <p>Induces sleep very quickly, but redistributed very quickly (5-10 mins)</p> <p>Is a dose dependant <i>potent</i> cardio-suppressant and venodilator</p>	<p>Normotensive dose: 3-7mg/kg. 70kg patient = 8-20 mls of standard solution</p> <p>Hypotensive dose: 0.1-0.5 of normal dose. 1.5-3.5mg/kg =4-10mls of standard solution</p>	<p>Cerebral protective (if CPP maintained)</p> <p>Reduces cerebral metabolic rate of oxygen (CMRO2)</p> <p>Will not mask hypovolaemia</p> <p>Raises seizure threshold</p> <p>Stable once drawn up</p>	<p>Needs mixing</p> <p>Will drop Mean Arterial Pressure (MAP) precipitously if not used cautiously</p>
Propofol	<p>Packaged as a ready made white emulsion in a break open glass bottle as 10mg/ml solution.</p> <p>Induces sleep quickly, redistributed quickly (5-10mins)</p> <p>Potent venodilator with no reflex tachycardia</p>	<p>Normotensive dose: 1-3mg/kg. 70kg patient = 7-21mls of standard solution</p> <p>Hypotensive dose: Not recommended for hypotensive patients unless very familiar with its use in hypotensive patients</p>	<p>Ready mixed</p> <p>Can be used to extend anaesthesia</p> <p>Useful as titrateable sedative</p> <p>Familiarity to many</p>	<p>Precipitous drop in MAP in hypotensive patients from whatever cause</p> <p>Cannot be pre drawn up</p>
Ketamine	<p>Packaged in premixed multi-dose glass vial in three concentrations; 10mg/ml (intravenous injection concentration), 50mg/ml and 100mg/ml.</p> <p>Stable once drawn up for 24 hours. There is a racemic mixture (UK and USA) but the stereo-selective S-isomer is available and is in widespread use in western Europe.</p> <p>Its pharmacodynamics are more favourable.</p> <p>Slower sleep onset time 30-60 secs. Anaesthesia for 10-20 mins</p> <p>Sympathomimetic: Excellent for hypotensive patients. Stabilises or increases MAP. Increase in MAP offsets increase in intracranial pressure and sustains cerebral perfusion pressure in TBI</p>	<p>Dose is 0.5-2mg/kg dependant on haemodynamic status.</p> <p>Always dilute to 10mg/ml concentration for IV use.</p> <p>70kg patient 3.5 – 14mls of 10mg/kg solution.</p>	<p>Ready mixed</p> <p>Maintains or increases MAP in hypotensive patients</p> <p>Bronchodilator, first choice for severely ill asthmatics</p> <p>Potent analgesic in sub-anaesthetic doses</p> <p>Avoids polypharmacy if also used as analgesic</p> <p>NMDA receptor antagonism in TBI theoretically useful</p> <p>Can be used IV, IN, IM and orally</p>	<p>Increases CMRO2</p> <p>Unfamiliarity</p>
Etomidate	<p>Packaged in break open glass vials as a premixed 2mg/ml solution</p> <p>Fast sleep onset time 15-45 secs. Anaesthesia for 3-12 mins</p> <p>Cardiovascularly stable for hypotensive patients</p>	<p>Dose is 0.3mg/kg</p> <p>70 kg patient requires ~10mls of premixed drug</p>	<p>Premixed: 2 preparations – Clear (Hypnomidate) and Fat emulsion (Lipuro) both 2mg/ml</p> <p>Stable in hypotensive patients</p>	<p>Suppresses steroid axis (exact outcome from a single bolus dose unknown)</p> <p>Unfamiliarity</p> <p>Pain on injection particularly with clear solution</p>

Table 1: The four main induction agents used for pre-hospital rapid sequence induction

Neuromuscular Blockers	General Information	Dose	Advantages	Disadvantages
Suxamethonium (Short Acting)	<p>Packaged as premixed solution in 2ml break open glass vials</p> <p>50mg/ml = 100mg per vial</p> <p>Induces paralysis very quickly, but redistributed very quickly dependant on metabolic rate and cardiac output. 3-7 mins</p> <p>Degrades once out of temperature range (2-7 Deg C) but will retain up to 90% efficacy for up to 3 months out of fridge (dependant on ambient temperature)</p>	<p>1.5-2mg/kg</p> <p>70kg patient</p> <p>= 105-140mg</p> <p>= 2-3 mls</p>	<p>Quick onset</p> <p>Familiarity</p> <p>Can be used IV and IM</p>	<p>Difficult storage (needs to be exchanged frequently in hot climates if not refrigerated)</p> <p>Nearly always require two vials</p> <p>Short duration of action</p> <p>Second doses can precipitate profound bradycardia especially in children</p> <p>Can cause cord spasm if not intubated before paralysis is extended leading to a "can't intubate/can't ventilate" scenario</p> <p>Some patients unable to metabolise drug leading to greatly lengthened paralysis time (hrs)</p>
Rocuronium	<p>Packaged as premixed solution in 5ml multi dose glass vials</p> <p>10mg/ml = 50mg per vial</p> <p>Only long acting NMB that induces paralysis as quickly as Suxamethonium at high doses (1.2mg/kg) and therefore an alternative to Suxamethonium for PHRSII, and maintains paralysis for 20-40 mins dependant on patient pharmacokinetics</p> <p>Specific reversal agent available (Sugammadex Schering-Plough, Schering-Plough House, Shire Park, Welwyn Garden City, Hertfordshire AL7 1TW)</p>	<p>1.2mg/kg.</p> <p>70kg patient</p> <p>= 84mg</p> <p>= ~9mls</p>	<p>Premixed</p> <p>Stable at ambient temperatures</p> <p>Reversible with Sugammadex</p> <p>Quick acting</p> <p>Long acting</p> <p>Negates need for second NMB post suxamethonium</p>	<p>Not compatible (in same IV line) with STP without flushing first</p>
Pancuronium	<p>Packaged as premixed solution in 2ml break open glass vials</p> <p>2mg/ml = 4mg per vial</p> <p>Longest acting paralytic with vagolytic properties that can help maintain MAP.</p>	<p>0.1mg/kg.</p> <p>70kg patient</p> <p>= 7mg</p> <p>= 3.5mls</p>	<p>Premixed</p> <p>Helps maintain MAP</p> <p>Longest acting NMB >40 mins dependant on patient pharmacokinetics</p>	<p>Need two vials in most patients</p>
Vecuronium	<p>Packaged as two vials. 5mls of sterile water in first break open glass vial and second glass vial containing vecuronium powder in glass vial. Vecuronium needs premixing before use. Once mixed solution is 2mg/ml = 10mg per 5ml vial</p>	<p>0.1mg/kg.</p> <p>70kg patient</p> <p>= 7mg</p> <p>= ~4mls</p>	<p>Familiarity</p> <p>Predicticable pharmacodynamics</p> <p>Reversible with Sugammadex</p>	<p>Needs premixing from two vials</p> <p>Very stable</p>

Table 2 The four Neuromuscular blocking agents used for pre-hospital rapid sequence induction

Specific Reversal Agents	General Information	Dose	Advantages	Disadvantages
Sugammadex	First-in-class reversal agent that encapsulates and inactivates rocuronium or vecuronium Packaged as premixed multi dose glass vial in 1ml (100mg), 2ml (200mg) and 5ml (500mg) volumes.	RSII reversal is 16mg/ml 70kg patient dose is 1120mg (11mls)	Complete and fast reversal of Rocuronium paralysis Shelf life 3 years	Expensive – RSII reversal costs approximately £350 (June 2010)

Table 3 The properties of a specific neuromuscular blockade reversal agent

Many of the studies in the literature focus on the process of intubation, rather than the process of anaesthesia to facilitate intubation. Drug use is important as both failed intubations and complications are reduced by the use of NMB drugs [25]. For this reason one should be extremely cautious using these studies to make conclusions about PHRSII.

Importantly the published evidence does not show RSII to be detrimental and, when delivered as part of a well governed system, may be beneficial. Services such as the Whatcom Medic One (Washington state) have a relatively small number of well-trained paramedics using a recognized PHRSII technique and report very good results [26]. Improved outcome has been demonstrated for patients transferred by helicopter compared to land ambulance [27]. This may be due to speed of transfer to hospital, better trained staff or a combination of both. Together this leads to the conclusion that small teams of well-trained staff on board helicopters are likely to improve outcomes if they are able to perform PHRSII in certain patients.

Attempting to tease out the exact benefits of PHRSII in the pre-hospital phase is difficult, but no more difficult than attempting to demonstrate the benefit of early intubation in the emergency department. Another facet to pre-hospital care is appropriate triage. Good evidence exists indicating that direct triage bypassing district general hospitals with TBI conditions such as extradural and subdural haematomas to regional neurological centres significantly reduces morbidity and mortality [28,29]. PHRSII is merely one component of a package of care provided by a pre-hospital critical care team.

Drugs

There are four main induction agents (Table 1) and four NMB drugs (Table 2) used in PHRSII. Table 3 lists the properties of a specific reversal agent for some NMB agents.

Training and standards

There is an obvious dichotomy between the fact that in hospital anaesthesia for a polytrauma patient would usually be carried out by the most senior available anaesthetist, whereas historically pre-hospital anaesthesia and intubation has been carried out by enthusiastic amateurs with little or no governance. This situation has recently been reviewed and a set of guidelines published by the AAGBI [16] with the support of the British Association of Immediate Care Schemes (BASICS), the Faculty of Pre-hospital Care at the Royal College of Surgeons of Edinburgh, the Royal College of Anaesthetists and the Military.

These guidelines state the accepted level of monitoring, operator experience and team composition for delivering anaesthesia. Not surprisingly the monitoring standards remain the same as those for in hospital anaesthesia and minimal standards being non-invasive blood pressure, oxygen saturation, heart rate monitoring and end tidal carbon dioxide. The guidelines suggest that those undertaking PHRSII should perform at least one intubation per month. Whether this should be simulated or “live” is not stated. The process of pre-hospital anaesthesia is a complex process requiring over 100 individual tasks. There is merit in practicing the process of intubation first in the elective surgical setting then progressing to high fidelity simulation to practice crew resource management to successfully assess, anaesthetise, resuscitate and package a patient in this challenging environment.

Courses do exist to train teams specifically to deliver PHRSII. These include the courses provided by the Great North Air Ambulance Service and the Mid Anglia General Practitioner Accident Service. They build team skills through realistic scenario training to familiarize providers with the procedures for anaesthesia, failed intubation drills, post intubation management and managing PHRSII as part of a complex pre-hospital scenario.

Conclusions

Taking anaesthesia to patients in the pre-hospital setting is a challenge in terms of individual skill and judgment and organization. The evidence base to support pre-hospital anaesthesia is by no means conclusive but what is clear is that outcomes are dependent upon the capabilities of the team delivering that care. PHRSII of anaesthesia should not just be seen as a treatment but merely one step in stabilizing a patient on a journey to definitive care.

References

- Harris T, Ellis D, Foster L, Lockey D. Cricoid pressure and laryngeal manipulation in 402 pre-hospital emergency anaesthetics: Essential safety measure or a hindrance to rapid safe intubation? *Resuscitation* 81: 810–816.
- Morris J, Cook TM. Rapid sequence induction: a national survey of practice. *Anaesthesia* 2001; **56**(11):1090-7.
- Davis DP, Fakhry SM, Wang HE et al. Paramedic rapid sequence intubation for severe traumatic brain injury: perspectives from an expert panel. *Prehosp Emerg Care* 2007; **11**(1):1-8.
- Joint Royal Colleges Ambulance Liaison Committee. A critical reassessment of ambulance service airway management in pre-hospital care. JRCALC Working Group.2008.

5. Fakhry SM, Scanlon JM, Robinson L et al. Pre-hospital rapid sequence intubation for head trauma: conditions for a successful program. *J Trauma* 2006; **60**(5):997-1001.
6. Gunning M, O'Loughlin E, Fletcher M, Crilly J, Hooper M, Ellis DY. Emergency intubation: a prospective multicentre descriptive audit in an Australian helicopter emergency medical service. *Emerg Med J* 2009; **26**(1):65-9.
7. Botker MT, Bakke SA, Christensen EF. A systematic review of controlled studies: do physicians increase survival with pre-hospital treatment? *Scand J Trauma Resusc Emerg Med* 2009; **17**(1):12.
8. Dickinson ET, Cohen JE, Mechem CC. The effectiveness of midazolam as a single pharmacologic agent to facilitate endotracheal intubation by paramedics. *Prehosp Emerg Care* 1999; **3**(3):191-3.
9. Bozeman WP, Young S. Etomidate as a sole agent for endotracheal intubation in the pre-hospital air medical setting. *Air Med J* 2002; **21**(4):32-5.
10. Warner KJ, Cuschieri J, Jurkovich GJ, Bulger EM. Single-dose etomidate for rapid sequence intubation may impact outcome after severe injury. *J Trauma* 2009; **67**(1):45-50.
11. Swanson ER, Fosnocht DE, Jensen SC. Comparison of etomidate and midazolam for pre-hospital rapid-sequence intubation. *Prehosp Emerg Care* 2004; **8**(3):273-9.
12. Stevenson AG, Graham CA, Hall R, Korsah P, McGuffie AC. Tracheal intubation in the emergency department: the Scottish district hospital perspective. *Emerg Med J* 2007; **24**(6):394-7.
13. Graham CA, Beard D, Oglesby AJ et al. Rapid sequence intubation in Scottish urban emergency departments. *Emerg Med J* 2003; **20**(1):3-5.
14. Reid C, Chan L, Tweeddale M. The who, where, and what of rapid sequence intubation: prospective observational study of emergency RSI outside the operating theatre. *Emerg Med J* 2004; **21**(3):296-301.
15. Mort TC. Emergency tracheal intubation: complications associated with repeated laryngoscopic attempts. *Anesth Analg* 2004; **99**(2):607-13.
16. AAGBI. Pre-hospital Anaesthesia. 2009.
17. NCEPOD. Trauma; who cares? 2007.
18. Gausche M, Lewis RJ, Stratton SJ et al. Effect of out-of-hospital pediatric endotracheal intubation on survival and neurological outcome: a controlled clinical trial. *JAMA* 2000; **283**(6):783-90.
19. Winchell RJ, Hoyt DB. Endotracheal intubation in the field improves survival in patients with severe head injury. Trauma Research and Education Foundation of San Diego. *Arch Surg* 1997; **132**(6):592-7.
20. Arbabi S, Jurkovich GJ, Wahl WL et al. A comparison of pre-hospital and hospital data in trauma patients. *J Trauma* 2004; **56**(5):1029-32.
21. Stockinger ZT, McSwain NE, Jr. Pre-hospital endotracheal intubation for trauma does not improve survival over bag-valve-mask ventilation. *J Trauma* 2004; **56**(3):531-6.
22. Murray JA, Demetriades D, Berne TV et al. Pre-hospital intubation in patients with severe head injury. *J Trauma* 2000; **49**(6):1065-70.
23. Eckstein M, Chan L, Schneir A, Palmer R. Effect of pre-hospital advanced life support on outcomes of major trauma patients. *J Trauma* 2000; **48**(4):643-8.
24. von Elm E, Schoettker P, Henzi I, Osterwalder J, Walder B. Pre-hospital tracheal intubation in patients with traumatic brain injury: systematic review of current evidence. *Br J Anaesth* 2009; **103**(3):371-86.
25. Bulger EM, Copass MK, Sabath DR, Maier RV, Jurkovich GJ. The use of neuromuscular blocking agents to facilitate pre-hospital intubation does not impair outcome after traumatic brain injury. *J Trauma* 2005; **58**(4):718-23.
26. Wang HE, Davis DP, Wayne MA, Delbridge T. Pre-hospital rapid-sequence intubation--what does the evidence show? Proceedings from the 2004 National Association of EMS Physicians annual meeting. *Prehosp Emerg Care* 2004; **8**(4):366-77.
27. Davis DP, Peay J, Serrano JA et al. The impact of aeromedical response to patients with moderate to severe traumatic brain injury. *Ann Emerg Med* 2005; **46**(2):115-22.
28. Tasker RC, Morris KP, Forsyth RJ, Hawley CA, Parslow RC. Severe head injury in children: emergency access to neurosurgery in the United Kingdom. *Emerg Med J* 2006; **23**(7):519-22.
29. London Severe Injuries Working Group. Modernising Major Trauma Centres in London. 2001.