PRE-HOSPITAL PAEDIATRIC INTUBATION

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A Research Report submitted to the Faculty of Health Sciences,

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requirements for the degree

Master of Science in Medicine in Emergency Medicine

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Declaration

I, Daniel Gavin Nevin declare that this research report is my own work. It is being submitted for the degree Master of Science in Medicine in Emergency Medicine to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

20th day of January 2014

For Professor Efraim B. Kramer - mentor, hero, friend.

And for the broken, damaged and injured who cannot look after themselves;

for those are the ones we serve…

Publications & Presentations

1. Podium presentation at the International Conference of Emergency Medicine (ICEM), Dublin, Ireland, June 2012 under the title *'Pre-Hospital Paediatric Intubation in a Physician-led Trauma Service'*.

2. Podium presentation at London Air Ambulance, Clinical Governance Day, London, England, October 2012 under the title *'Pre-Hospital Paediatric Intubation in a Physician-led Trauma Service'*.

3. Published in Resuscitation, October 2013 under the title *'An observational study of paediatric pre-hospital intubation and anaesthesia in 1933 children attended by a physician-led, pre-hospital trauma service'*.[1] (Appendix 1)

Abstract

Introduction

Trauma accounts for 16-44% of childhood deaths. The number of severely injured children who require pre-hospital advanced airway management is thought to be small, but there is little published data detailing the epidemiology of these interventions. This study was designed to evaluate the children who received pre-hospital intubation (with or without anaesthesia) in a high volume, doctor-led, pre-hospital trauma service and the circumstances surrounding the intervention.

Methods

A 12 year retrospective database analysis was conducted. All paediatric patients (<16 years of age) that were attended and received pre-hospital advanced airway management were included. The total number of pre-hospital intubations and the proportion that received a rapid sequence intubation (RSI) were established. To illustrate the context of these interventions the demographics, injury mechanisms, intervention success rates and scene times were recorded.

Results

Between 1 January 2000 and 31 October 2011 the service attended 1933 children. There were 315 (16.3%) pre-hospital paediatric intubations. Of those intubated, 81% received an RSI and 19% were intubated without anaesthesia in the setting of near

or actual cardiac arrest. Nearly three quarters of the patients were in the age range of 6 -15 years with only 3 patients under the age of 1 year. The most common injury mechanisms that required intubation were road traffic crashes (RTCs) and 'falls from height'. These accounted for 79% of patients receiving intubation. Intubation success rate was 99.7% with a single failed intubation during the study period. Mean on-scene time was 41 minutes when RSI was delivered.

Conclusion

Pre-hospital paediatric intubation is not infrequent in this high-volume trauma service. The majority of patients received an RSI. The commonest injuries associated with intubation were blunt trauma caused by RTCs and 'falls from height'. Pre-hospital paediatric intubation is associated with a high success rate in this service.

Acknowledgements

I wish to extend thanks to Richard Lyon, David Lockey, Anne Weaver and the men and women of the London Air Ambulance, without which this research report would not be possible.

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Definitions

Accident involving machinery – A traumatic incident whereby the victim has been injured by industrial machinery. May or may not involve entrapment of the victim.

Advanced airway management - The medical procedures used to maintain an open conduit from the environment to the lungs of a patient while reducing the risk of aspiration. Includes intubation (with or without anaesthesia).

Anaesthesia – (Or general anaesthesia) is the induction of a state of unconsciousness by the administration of anaesthetic drugs or medications. Pre-hospital anaesthesia is generally administered for the purposes of facilitating intubation and typically uses the technique of Rapid Sequence Intubation.

Animal Incident – A traumatic incident whereby the victim has sustained an injury either during or after interaction with an animal. This is usually a domestic animal but may be a wild animal.

Intubation – (or endotracheal intubation) is the placement of a flexible, hollow plastic tube into the trachea to maintain a patent airway and to serve as a conduit for artificial ventilation.

Paediatric – Of, or relating to, the medical care of children. In this study 'children' or 'paediatric' refers to any patients less than 16 years of age (including new-borns).

Pre-hospital - Occurring before arrival or during transportation to a hospital.

Rapid Sequence Intubation (RSI) – A medical procedure resulting in the rapid induction of general anaesthesia and subsequent endotracheal intubation. It is synonymous with 'pre-hospital anaesthesia' in this study.

Where distinction is made between 'intubation' versus 'RSI'; 'intubation' refers to the performance of this procedure **without** anaesthesia; and 'RSI' as defined above, refers to the performance of intubation **with** anaesthesia.

Unarmed fight – A traumatic incident whereby the victim is assaulted by one or more people, without the use of weapons.

Chapter One

Introduction

1.1 Introduction

Trauma accounts for a large proportion of childhood mortality and is the leading cause of death in those aged 1-44 years.[2-4]

Although airway and ventilation problems have been identified as key issues in critically injured trauma victims, limited publications exist on pre-hospital paediatric advanced airway management.[2,5-8] This is likely a result of multiple factors: few children sustain injuries severe enough to require pre-hospital anaesthesia and intubation;[2,5-8] simple airway manoeuvres are usually adequate to treat early airway compromise in children;[6,8] and individual exposure of Emergency Medical Services (EMS) providers to severely injured children is relatively infrequent.[4,9] There exists a perception that pre-hospital anaesthesia and intubation in children is rarely required and challenging to deliver safely.[3,6]

A safety guideline published by The Association of Anaesthetists of Great Britain and Ireland (AAGBI) recommends that pre-hospital anaesthesia and intubation in children should only be performed by a skilled, anaesthetic-trained practitioner, where simple airway manoeuvres and oxygen therapy have failed to provide a patent airway and adequate oxygenation.[6] The guideline suggests that even in relatively advanced systems, the threshold for pre-hospital paediatric anaesthesia and intubation should be relatively high.[6]

However, it is likely that in a small number of patients intubation is required to provide and maintain a definitive airway and can be lifesaving in critically injured children if delivered rapidly and safely.[4-6]

1.2 Problem Statement

Paediatric pre-hospital anaesthesia and intubation have previously been reported to be rare.[5,6] Recent studies in the United Kingdom (UK) have identified a lack of comprehensive data on advanced airway management, particularly pre-hospital anaesthesia and intubation in acutely injured children.[6,9,10] Although several studies have addressed pre-hospital airway management in adults;[11-13] trauma patterns in children;[2,4] and pre-hospital interventions in children;[3,14] few have specifically evaluated pre-hospital paediatric Rapid Sequence Intubation (RSI) or intubation without anaesthesia.[5,6,9] This may be because few services attend sufficiently high numbers of paediatric trauma patients to accumulate meaningful samples of patients to report.[4,5,10]

The lack of published data has stimulated various authorities to suggest that this subject is a priority area in pre-hospital research.[10] A need to further describe the circumstances and details surrounding paediatric pre-hospital advanced airway management exists. Quantification of the epidemiology of paediatric pre-hospital anaesthesia and intubation is necessary to fill a knowledge gap, establish a framework of understanding, inform on clinical practice and direct training of EMS providers.

1.3 Aim of the Study

The aim of this study was to report on issues surrounding pre-hospital paediatric anaesthesia and intubation.

1.4 Objectives of the Study

- To describe the frequency and demographic profile of pre-hospital anaesthesia and intubation in paediatric patients.
- To describe the types of traumatic incidents commonly encountered by paediatric patients and their association with subsequent pre-hospital anaesthesia and intubation.
- To describe the success rate of pre-hospital anaesthesia and intubation in paediatric patients and to critically evaluate unsuccessful events.
- To describe the differences in scene-time when pre-hospital anaesthesia and intubation was delivered.

1.5 Relevance

The pre-hospital environment is complex; and rendered emergency medical care must match the standard delivered in-hospital.[3] Paediatric trauma patients are time-critical and difficult to manage.[5,15] High risk medical procedures that are performed infrequently must be delivered timeously, effectively and with a minimum of risk to the patient.[3,6] Refining pre-hospital paediatric advanced airway management is thus considered fundamentally important.[10]

1.6 Outline of Report

The research report takes the following format:

- Chapter One: Introduction of study
- Chapter Two: Review of the relevant literature
- Chapter Three: Methodology and statistical analysis
- Chapter Four: Presentation of findings
- Chapter Five: Discussion of results
- Chapter Six: Conclusions, limitations and recommendations
- Appendices
- References

1.7 Summary

This chapter provides a background framework of the clinical environment and existing knowledge gap. It has described the aim, intentions and relevance of the study and provides a summary of the report to follow.

Chapter Two

Literature Review

2.1 Introduction & Epidemiology

Trauma accounts for a large proportion of childhood mortality and is the leading cause of death in those aged 1-44 years.[2-4]

Despite this, no data had been analysed on paediatric trauma in the United Kingdom (UK) until recently.[2] This took the form of assessment of the Trauma Audit and Research Network (an anonymous data collection network representing 60% of trauma-receiving hospitals in England and Wales) evaluating 24 000 patients over a 15 year period.[2]

The following was revealed:[2]

- The median age of children presenting with serious injury was 9.5 years and injury tends to increase with age.
- Limb and head injuries were the most frequently injured anatomy, occurring in 65% and nearly 25% of cases respectively.
- An inverse trend between these occurred with head injuries diminishing with advancing age and an associated concomitant rise in limb trauma.
- The commonest causes of paediatric trauma were Road Traffic Crashes (RTCs) and 'falls from height' representing 40.9% and 36.9% respectively. Assault (1.9%) and Sport Injuries (0.2%) had significantly lower representation.

- An overall mortality rate of 4.2% for paediatric trauma was observed to decline to 3.1% over the period 1990-2005. This was highest in the <1year age group and lowest in the 6-10 year group.
- Mortality was highest in head or multiply injured children (head + thorax or head + abdomen) rather than in isolated injuries.
- Presentation to the emergency department wide awake was associated with a low mortality (0.2%) but any decreased level of consciousness demonstrated a significantly higher mortality (16%).

No data has been published on pre-hospital paediatric trauma for the UK. Relevant research on pre-hospital paediatric trauma was a study by Eich et al describing paediatric attendances on a Helicopter Emergency Medical Service (HEMS) in Germany.[4] In this 9 year retrospective review of 2200 patients, the authors believed their data to be reasonably representative of the urban pre-hospital environment in other central European countries.[4]

They declared that in general, advanced paediatric interventions were uncommon, but when required, advanced airway management was most frequently required.[4] Attendances requiring frequent paediatric pre-hospital intubation included drowning, serious head injury and burns.[4] A high attendance to incidents involving children <1year of age (14%) was noted. Attendances were also noted to increase with advancing age.[2,4,5] They concluded that pre-hospital intubation was a necessary and important skill for their doctors.[4]

2.2 Pre-hospital Paediatric Care

The incidence of paediatric patients transported to hospital by the EMS is 5-10%.[4,10,16-19] Thus the exposure of individual EMS providers to severely injured children is infrequent and may result in a lack of ability, experience and confidence when approaching critically injured children.[4,6,8,9,16,19,20]

Paediatric trauma patients are a can be difficult to manage, are often time critical and have the potential to overwhelm inexperienced EMS providers.[4,20,21] As a result, there has been the suggestion that the pre-hospital care of children may be suboptimal in comparison with adults.[4,20] This may translate into unfavourable outcomes that are potentially preventable.[4,20] Particular problems identified include the appropriateness and safety of advanced paediatric airway management (specifically pre-hospital intubation) and associated high complication rates.[20]

2.3 Pre-hospital Paediatric Intubation

Although airway and ventilation problems have been identified as key issues in critically injured patients, few children sustain injuries severe enough to require pre-hospital anaesthesia and intubation.[2,4-814,20,22] Furthermore, simple airway manoeuvres are usually adequate to treat early airway compromise in children.[6,8] Because paediatric pre-hospital intubation is a clinical challenge and potentially hazardous[5,8,9] these factors have led to divided opinion as to the most appropriate approach to children requiring pre-hospital advanced airway management.[11,12,23]

Airway compromise is a preventable cause of morbidity and death in trauma and cardiac arrest.[11,12,22] Therefore an important goal of pre-hospital care is the is addressing this and optimising patient physiology before or during transport to hospital.[19,21] Adequate, appropriate, airway management, oxygenation and ventilation are crucial.[19,21]

Historical reluctance towards pre-hospital paediatric intubation arose from high documented complications by EMS providers and a lack of evidence demonstrating benefit for the procedure.[3,5,6,8,18-21,24] Success rates in early studies for paediatric pre-hospital intubation ranged from 56 to 95%[5] with one investigation revealing a nearly four-fold difference in intubation failures in children vs. adults (36% vs. 9%).[8]

Gausche et al showed no difference in death or neurological outcome in children with head injury regardless of whether they received pre-hospital intubation or were oxygenated with bag-valve-mask ventilation during delivery to hospital.[3] The reason cited for such a staggering failure rate was paediatric anatomical differences which are a consistent theme in other similar research.[3,8,19-21] A Cochrane Review performed in 2008 declared 'There is insufficient evidence to further extend the existing practice of paediatric pre-hospital intubation in the urban environment.'[5,25]

However, it is likely that in a small number of patients intubation is required to provide and maintain a definitive airway and can be lifesaving in critically injured children if delivered rapidly and safely.[4-6,11,12] Effective management of the airway may have the greatest impact on mortality and morbidity of all pre-hospital interventions.[15] Furthermore the administration of pre-hospital anaesthesia and intubation may reduce time to definitive care.[15]

The quality, safety and success of anaesthesia and intubation may be related to the skill and experience of the person performing the procedure.[5,11,21] There are considerable variations in the training, experience and on-going exposure of EMS providers in different pre-hospital systems.[11,26] Much of the research conducted has occurred in such heterogeneous systems and is not directly comparable.

Currently there exists no evidence-based recommendation or consensus that defines the environment, patient or provider-related criteria for pre-hospital intubation of children.[5,21] Despite this, paediatric airway management skills are still considered 'essential' in practitioners involved in the regular delivery of paediatric pre-hospital care[4,27] and intubation is the acceptable standard for securing the airway definitively.[4,15,27]

As a result of the conflicting opinion regarding the role and safety of pre-hospital intubation[3,11,12,18] and because when performed poorly it can be harmful[3,6,11,12,21,22] scrutiny has fallen to the systems performing pre-hospital intubation. The personnel, training levels, on-going exposure and techniques have become relevant.

Intubation success rates are considered a quality marker of the system.[11] Doctor based systems consistently out-perform paramedic based systems with success rates in the order of 97 to100% (highest if the doctors have had anaesthesia training).[5,11,12,21] This has been demonstrated even in systems where exposure rates were very low. A notable example was a system where providers performed with high rates of success despite conducting on average only one pre-hospital paediatric intubation every 3 years, and one per 13 years on children <1 year of age.[5]

2.4 Rapid Sequence Intubation

The AAGBI guidelines recommend that pre-hospital anaesthesia in children should only be performed by a skilled, anaesthetic-trained practitioner, where simple airway manoeuvres and oxygen therapy have failed to provide a patent airway and adequate oxygenation.[6] They also suggest that even in relatively advanced systems, the threshold for pre-hospital paediatric anaesthesia and intubation should be relatively high.[6] However, should they be performed, the recommended technique is Rapid Sequence Intubation (RSI).[15] In general, children who are obtunded to the point of absent airway reflexes or those in cardiac arrest do not require RSI.[19]

RSI is the procedure of choice for most in-hospital emergency intubations and is associated with the highest success rate and lowest incidence of complications.[11,15,19,22,28,29] It is currently advocated by the Paediatric Emergency Medicine Committee of the American College of Emergency Physicians and the ILCOR 2010 Guidelines (International Liaison Committee on Resuscitation).[27,28]

RSI is recommended for children[22] is particularly recommended in the pre-hospital environment[15] and is a core component of pre-hospital care in many European countries.[11] However use of RSI requires a high level of competence and the ability to deal with potentially life threatening adverse effects or complications.[6,11]

There are likely specialised, training requirements to perform safe pre-hospital RSI to the same standard as in-hospital, though these are not clearly known, nor is a threshold for sufficient experience described or validated.[15,19,21,27] Currently this has been left to the discretion of the system performing RSI.[27]

2.5 Scene Time

The time between injury and definitive care has been recognised as being critical to trauma patient survival.[13,18] EMS providers are encouraged to minimise delays and rapidly expedite hospital transport without unduly prolonging scene time.[13,18]

Pre-hospital intubation is known to be more difficult than the controlled in-hospital counterpart[5] and has been shown to prolong scene time (on average) by a further ten minutes than when it is not performed, leading to concerns about impact on patient outcomes.[13,18]

Kulla et al reviewed scene times in patients receiving certain pre-hospital interventions (including intubation). They demonstrated two phenomena: patients receiving more pre-hospital interventions were more severely injured, (yet arrived in the emergency department with significantly improved vital parameters in comparison to less severely injured patients); and in-hospital treatment times were shorter in the patients that had received their interventions pre-hospital. Overall, there was no difference in the total resuscitation times between groups. Importantly, the pre-hospital intervention group did not have total resuscitation times that were longer than the non-intervention group.[13]

2.6 Research Priorities

The perception that pre-hospital paediatric RSI is rarely required and challenging to deliver safely,[3,6] may contribute to the scarcity of publications on the subject. Research on pre-hospital paediatric care is crucial to determine its safety and efficacy and improve outcomes.[10]

Recent studies in the UK have identified a lack of comprehensive data on advanced airway management, particularly pre-hospital anaesthesia and intubation in acutely injured children.[6,9,10] Although studies have addressed trauma patterns in children[2,4] and pre-hospital interventions in children,[3,14] few have specifically evaluated pre-hospital paediatric anaesthesia and intubation.[5] This may be because few services attend sufficiently high numbers of paediatric trauma patients to accumulate meaningful samples of patients to report.

The lack of published data on this subject has stimulated various authorities to suggest that this subject is a major priority area in pre-hospital research.[10,11,18]

2.7 Summary

The known epidemiology pertaining to trauma patterns in children in the UK have now been described. The difficulties and controversy relating to pre-hospital paediatric advanced airway management have been described as have the relevant issues around safe and appropriate delivery of pre-hospital RSI with emphasis on the success rates. There was a description of the relevance and importance of scene time and an explanation of the remaining knowledge gaps in pre-hospital paediatric care. The platform and baseline of knowledge has now been established making the purpose and aims of the study more relevant and better understood.

Chapter Three

Methodology

3.1 Introduction

This chapter is devoted to the methodology and conduct of the study and includes a description of the study environment, research methods used, data collection and mathematical analysis.

3.2 Study Setting

The study was carried out in the London Air Ambulance (LAA) Service. This is an urban, doctor-led, pre-hospital trauma service, serving a daytime population of up to 10 million people in an area approximately 5,000 square kilometres.

The operational team (doctor and paramedic) is delivered to incidents by helicopter in the daytime and by fast response car at night. The service is dispatched only to trauma patients, specifically those with severe injury. Deployment is rapid and flight times across London are short. The service attends an average of 5 to 6 trauma patients per day.

Scene time is logged by the control room when the helicopter lands on the ground or the rapid response vehicle arrives at the incident. Departure from the scene is similarly communicated to the control room when the transport vehicle (land ambulance or helicopter) departs carrying the patient. This entire time period (including transport to the actual incident from the helicopter landing site, handover from the ground crew, extrication (as necessary) and patient treatment) constitutes the recorded scene time. Patients are delivered directly to specialist centres as appropriate, thus avoiding delays to definitive care.

Doctors are experienced anaesthetists or emergency physicians with a minimum of 6 months of in-hospital anaesthetic training. Most doctors have some prior pre-hospital experience. Further in-post training is provided in a 4-6 week induction period under the guidance and supervision of pre-hospital care specialists. Weekly case review, audit and clinical governance meetings and intermittent specialist supervision ensures consistency with service protocols and maintenance of service standards. Flight paramedics have specific in-service training to equip them as members of the pre-hospital anaesthesia team.

Pre-hospital anaesthesia is conducted using the technique of RSI and is carried out in line with UK recommendations on pre-hospital anaesthesia[6] and according to local standard operating procedures (SOP) (Appendix 2). Indications for pre-hospital RSI are: 1) Actual or impending airway compromise; 2) Ventilatory failure; 3) Unconsciousness or profound cerebral agitation; 4) Anticipated clinical course; 5) Humanitarian reasons.

The local service SOP for RSI is robust and has been practiced for over 10 years. It has seen the performance of over 7000 pre-hospital RSIs with a high intubation success rate.[12] A standardised and reproducible technique is used and the on-scene doctor has a limited number of treatment choices to make. In the study period etomidate was used to induce anaesthesia and suxamethonium was used for initial muscle relaxation. Intubation was carried out by the doctor with the routine use of an intubating catheter (Cook Medical, Frova airway intubating catheter™). When patients are in established or impending cardiac arrest, intubation is conducted without anaesthesia.

Equipment for failed intubation includes a supraglottic airway device (laryngeal mask airway) and equipment for surgical cricothyroidotomy. Correct tube placement is confirmed by the use of colourimetry and digital capnography. A mechanical ventilator is available to ventilate patients after intubation (Drager Oxylog 2000™).

The SOP allows for a maximum of two initial attempts at intubation. A set of operator drills to improve laryngoscopy are followed if there is failure at the first attempt. Further failure to intubate leads the practitioner down a pathway to either placement of a laryngeal mask airway or a surgical airway. A third alternative, (bag-valve-mask ventilation and transport to hospital) exists for patients in whom a surgical airway is undesirable or impossible. At least two good attempts at intubation must be performed.

All members of the service are drilled in the procedures and regularly practice in a low fidelity simulation environment. In keeping with the AAGBI guidelines, the SOP emphasizes that the threshold for pre-hospital paediatric anaesthesia is higher than that for pre-hospital adult anaesthesia and only be conducted when absolutely necessary.[6] Where possible, prior to performing pre-hospital paediatric anaesthesia, the decision is discussed with an on-call pre-hospital specialist. This is to discuss equivocal cases or to assist with determining risk/ benefit analysis where the risk is felt to be extremely high or the benefit to be limited. This aspect of clinical governance and oversight is felt to be desirable when on-scene conditions are especially challenging.

3.3 Study Population

All patients under the age of 16 years attended by the LAA from midnight January 1^{st} 2000 to midnight October 31^{st} 2011 were studied.

Inclusion Criteria

- Trauma victims under the age of 16 years
- Attended by the LAA from midnight January 1^{st} 2000 to midnight October 31^{st} 2011
- Received the intervention of RSI or intubation were evaluated.

Exclusion Criteria

- Patients attended by the LAA that were 16 years or older
- Patients that were not victims of trauma
- Patients that did not receive the intervention of RSI or intubation

3.4 Study Design

Standard patient data on patients attended by the LAA is prospectively recorded on a Microsoft ACCESS™ database as a matter of routine. A retrospective database review was conducted on patients attended during the study period. This study involved analysis of the accumulated, standardised system data. No additional data was collected and no additional interventions were carried out.

All patients attended by the service under the age of 16 years were initially evaluated to establish total number of attendances, RSIs and intubations. Thereafter patients attended that were victims of trauma and had received the intervention were subsequently evaluated. Patient demographics, injury descriptors and relevant time indices were recorded in a Microsoft EXCEL™ database for analysis (Appendix 3). Mission reports (standardised pro forma) (Appendix 4) of every case of pre-hospital RSI or intubation were then evaluated to look for additional detail including complications or failed intubations. Cross referencing on all patients who received RSI or intubation with original mission report forms was also conducted in order to confirm the accuracy of the data and elicit further detail.

3.5 Ethical Considerations

Ethical approval for the study was obtained from the Human Research Ethics Committee (Medical), Faculty of Health Sciences, University of the Witwatersrand (Appendix 5). Permission for access to the operational database was obtained from the Medical Director of the London Air Ambulance (Appendix 6).

The database and intellectual property belong to the LAA. All captured data was held in password protected Microsoft EXCEL ™ format and saved on a password protected computer at the premises of the LAA. Paper mission reports were reviewed confidentially at the premises of the LAA. These remained the property of the LAA and were kept locked within a fire proof safe at the LAA premises in Whitechapel, London. No identifying features pertaining to individual patients were used during the evaluation or description of the data.

Research was conducted according to the principles of the Declaration of Helsinki.[30]

3.6 Data Analysis

The following was elicited:

- Frequency and demographics – Incidence of paediatric attendances versus total attendances; incidence of RSI vs. intubation; age profiles for intervention; gender differences for intervention; time of day of intervention.
- Injury profile – Paediatric injury profile; association of injury type with RSI/ intubation.
- Success rate – Documented complications/ episodes of intubation failure and circumstances surrounding same.
- Scene time – Duration of scene time when RSI/ intubation performed vs. no intervention.

3.7 Statistical Analysis

Data collected included frequency of intubation, age, gender, time of day, mechanism of injury and scene times/ duration. Statistical analysis was applied using multinomial logistic regression. Relative risks and 95% confidence intervals were calculated and where appropriate descriptive statistics for continuous variables were expressed as medians with interquartile ranges using the Wilcoxon Rank Sum test. Statistical significance of data where relevant ($p<0.001$) was calculated and reported. Analysis was performed in Microsoft EXCEL™ and STATA v10.

3.8 Research Methodology

The study was a retrospective observational study with exploratory, contextual, quantitative and descriptive design elements.

Retrospective review of prior mission data from callouts attended by the LAA made the study retrospective. The observational component is described because the study evaluated a procedure already being performed in a defined population and drew observations within and about this group and procedure. This study had not previously been conducted and represented an index study with the purpose of directing future research and was therefore exploratory. The study was contextual as it was limited to a single site. The study was quantitative because the data collected was numerical and underwent further statistical analysis. Finally, because the study described an already existing 'real-world' environment and described a procedure within a population and its relative role, it was a descriptive work.

3.9 Summary

This chapter concludes a description of the environment, population and methods used to conduct the study and details how the data was collected and analysed.

Chapter Four

Results

4.1 Introduction

This chapter is concerned with the findings obtained after conduct of the study as outlined in the previous chapter. The results are described in numerical, tabulated and graphical format for ease of understanding.

4.2 Frequency of Intubation

During the study period from midnight January 1st 2000 to midnight October 31st 2011 a total of 14,716 trauma patients were attended and 3509 (23.8%) received pre-hospital intubation. Of these attendances 1933 (13.1%) were children (<16 years of age) resulting in 315 (9%) of the 3509 pre-hospital intubations being carried out on children. This accounted for the procedure being administered in 16.3% of all paediatric patient attendances. An average of 26.6 intubations was carried out per year on children compared to 269.9 per year on adults. A breakdown of these pre-hospital intubations revealed 255 (81%) of the paediatric patients received RSI and 60 (19%) were intubated without anaesthesia. The intubation success rate was 99.7% (1 failed intubation out of 315). (Figure 4.1)

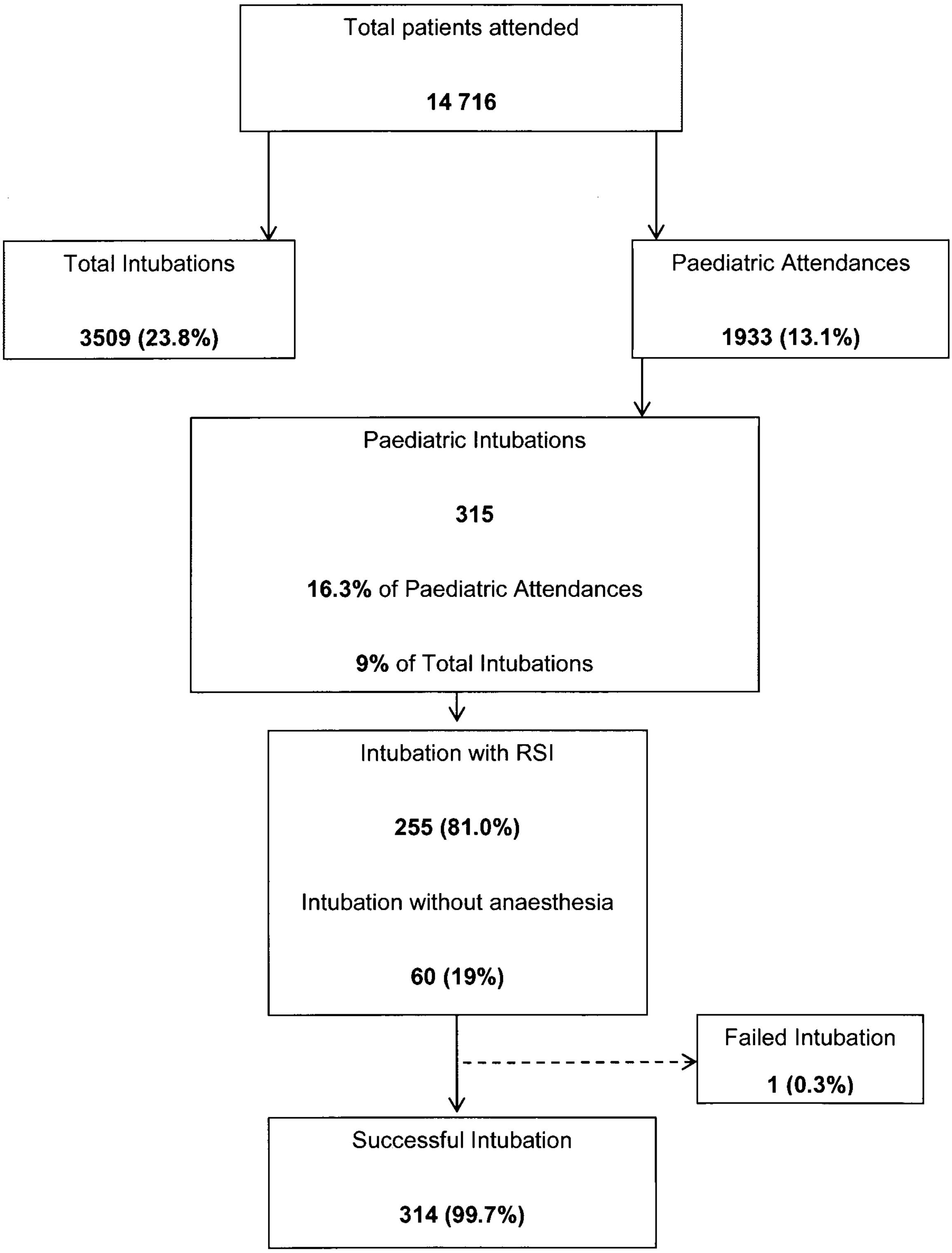

Figure 4.1 Schematic of pre-hospital intubations from January 1st 2000 to October 31st 2011

4.3 Demographic Profile

The demographic profile of paediatric pre-hospital intubation was described and broken down into age, gender and time of day of occurrences.

4.3.1 Age

315 children received pre-hospital intubation. The mean age was 9.36 years. The median age was 10 years. The mode was 14 years.

Grouping the ages for ease of comparison showed that 3 children (1%) were under the age of 1 year, 78 (24.8%) were aged 1-5 years, 77 (24.4%) were aged 6-10 years and 157 (49.8%) were aged 11–15 years. (Figure 4.2 and Figure 4.3)

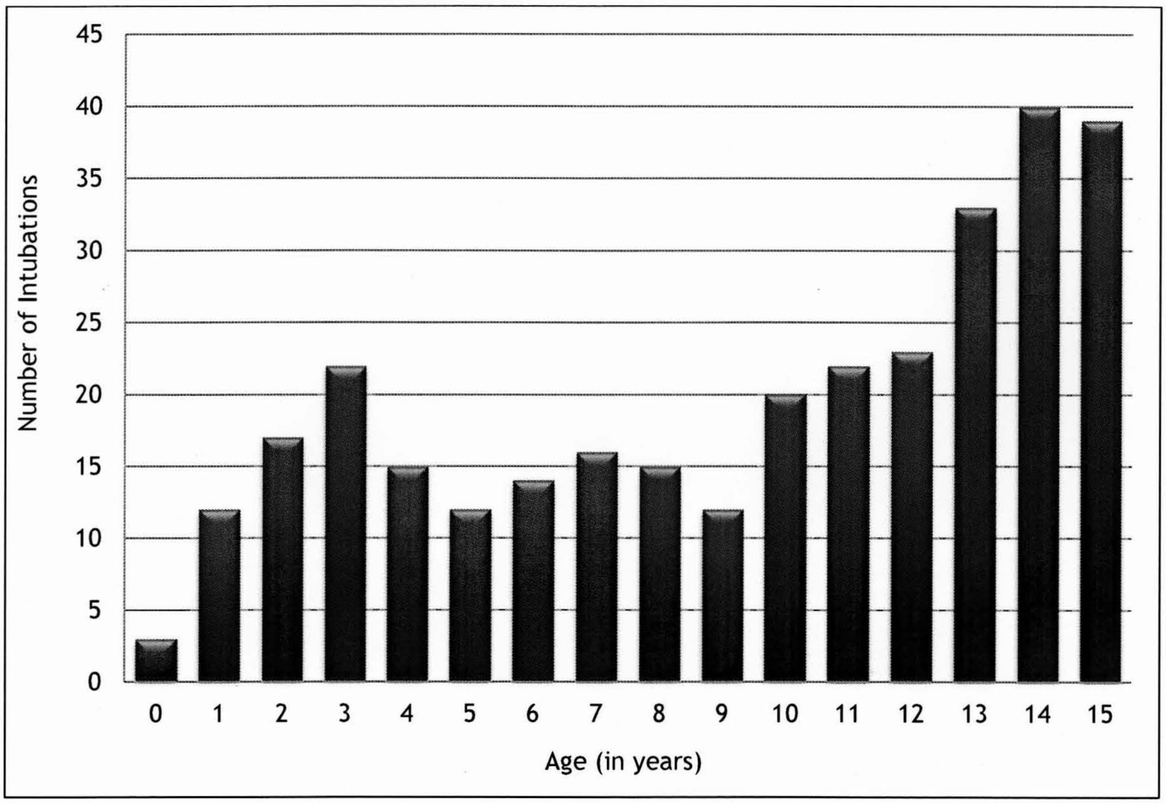

Figure 4.2 Pre-hospital paediatric intubations by age

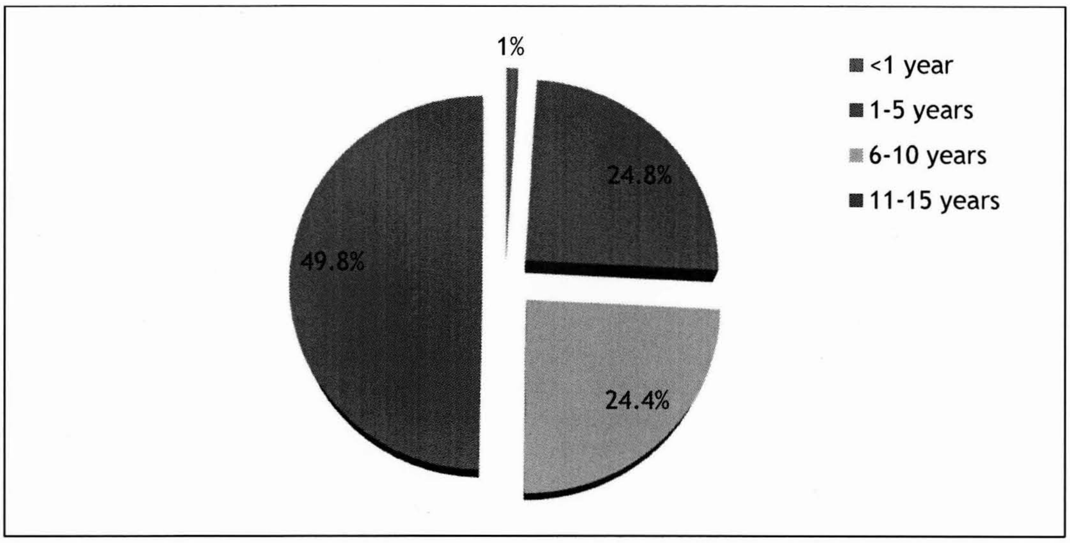

Figure 4.3 Relative number of pre-hospital paediatric intubations by age range

4.3.2 Gender

Of the 1933 paediatric attendances, 1333 (69%) were male and 600 (31%) were female. Of the children that received pre-hospital intubation 209 (66.3%) were male and 106 (33.7%) were female. Overall 15.68% of the males attended were intubated and 17.67% of the females attended were intubated. A similar proportion of male to female attendance and male to female intubation was observed. The difference was not significant. (P=0.2374; two sample t-test between percent) (Figure 4.4)

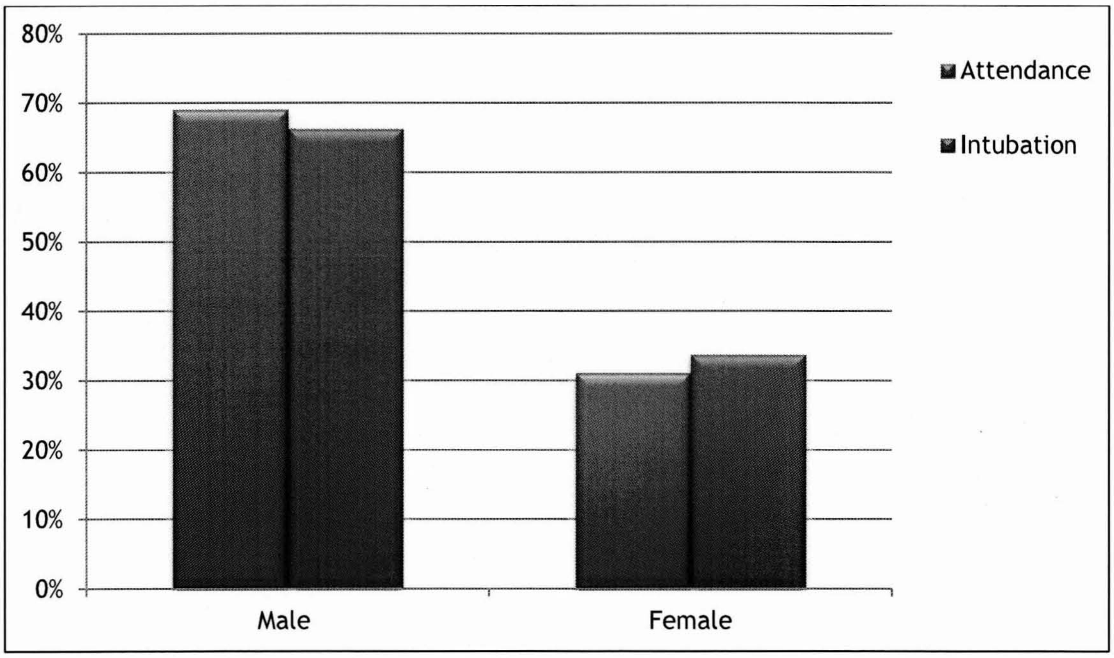

Figure 4.4 Relative proportions of paediatric attendances and intubations by gender

4.3.3 Time of Day

Data on time of day of intubation was only available for 297 patients. The frequency of intubation was observed to vary with the time of day. Peaks occurred at 13:00, 15:00 and 17:00. This was similar regardless of whether patients received RSI or intubation without anaesthesia. For the RSI group, 75% percent of the procedures took place between 12:00 and 19:00 and for the intubation without anaesthesia group 64.9% of the intubations took place during the same period. Few paediatric intubations (15 in total) occurred after 22:00. (Figure 4.5)

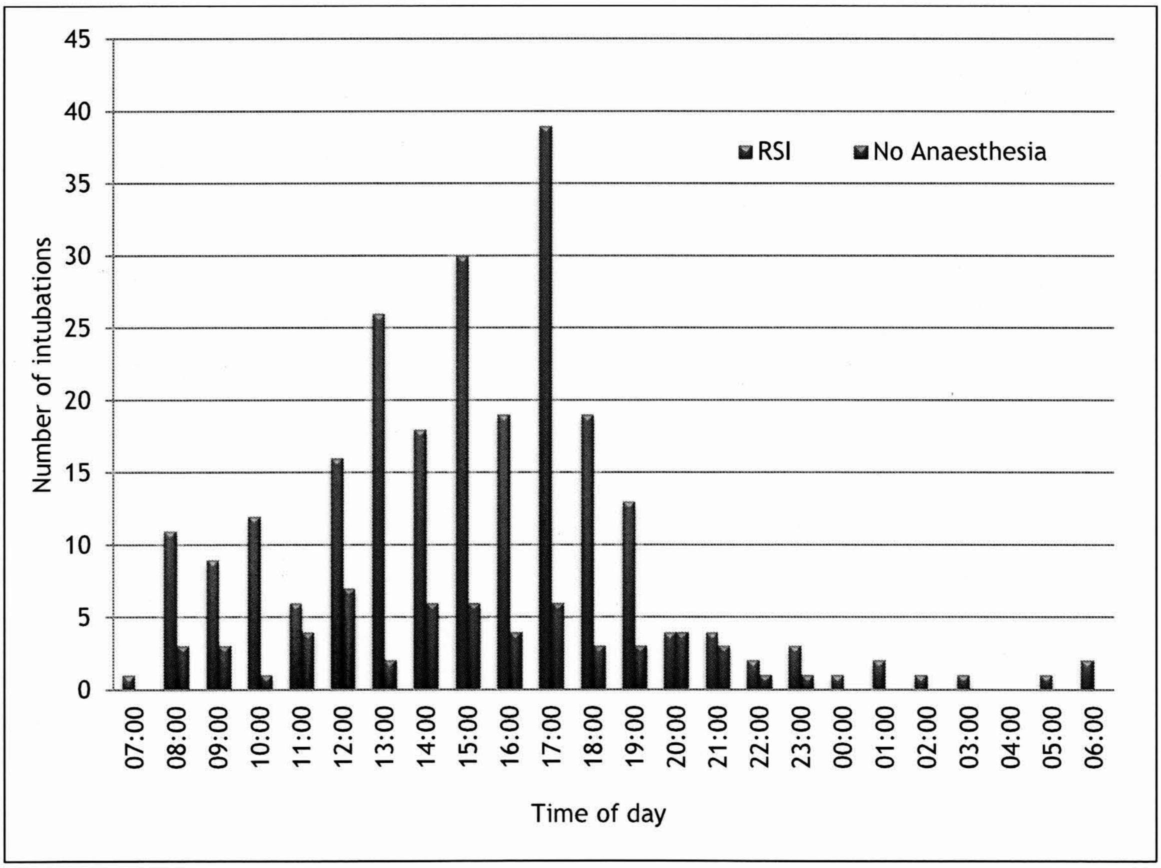

Figure 4.5 Pre-hospital paediatric intubations by time of day

4.4 Mechanism of Injury

All of the patients attended had a clearly identified mechanism of injury recorded in the database. These were selected from a pre-populated list of common injury identifiers during database entry. In total 309 patients' sustained traumatic injuries and 6 turned out to not be victims of trauma. Table 4.1 shows the mechanism of injury for all patients who received an RSI or intubation. Blunt trauma accounted for the majority requiring the procedure with road traffic crashes (RTCs) and 'falls from height' accounting for 60.5% (n=191) and 18.5% (n=58) respectively.

Of the patients that were not victims of trauma, 3 had suffered a medical cardiac arrest with a Return of Spontaneous Circulation (ROSC), 1 patient suffered severe seizures, 1 patient had collapsed from an unknown cause and 1 had suffered a choking incident. This data is included for completeness but hereafter these patients are considered no further.

More detailed evaluation of children involved in RTCs demonstrated the majority of these patients were either pedestrians struck by vehicles (73.3%) or pedal cyclists (12.6%). One child was the driver of a motor vehicle. (Table 4.2)

Mechanism of injury	<1 year		1-5 years		6-10 years		11 - 15 years		Total
	RSI	No Anaes	RSI	No Anaes	RSI	No Anaes	RSI	No Anaes	
Accident involving machinery	0	0	0	4.5% (n=1)	0	0	0	0	**0.3% (n=1)**
Animal incident	0	0	0	0	0	0	0.7% (n=1)	0	**0.3% (n=1)**
Burns	0	0	8.9% (n=5)	0	1.6% (n=1)	0	3.0% (n=4)	0	**3.2% (n=10)**
Drowning	0	0	3.5% (n=2)	27.3% (n=6)	3.2% (n=2)	6.7% (n=1)	0.7% (n=1)	14.3% (n=3)	**4.8% (n=15)**
Fall from height	0	100% (n=2)	44.6% (n=25)	4.5% (n=1)	16.1% (n=10)	13.3% (n=2)	11.1% (n=15)	14.3% (n=3)	**18.5% (n=58)**
Hanging	0	0	0	4.5% (n=1)	0	6.7% (n=1)	1.5% (n=2)	14.3% (n=3)	**2.2% (n=7)**
Penetrating trauma	0	0	1.7% (n=1)	4.5% (n=1)	0	13.3% (n=2)	4.4% (n=6)	14.3% (n=3)	**4.1% (n=13)**
Road traffic crash	0	0	37.5% (n=21)	50% (n=11)	79.0% (n=49)	46.7% (n=7)	70.4% (n=96)	33.3% (n=7)	**60.5% (n=191)**
Struck by object/ person	100% (n=1)	0	1.7% (n=1)	0	0	6.7% (n=1)	3.0% (n=4)	0	**2.2% (n=7)**
Suffocation	0	0	0	4.5% (n=1)	0	0	3.0% (n=4)	0	**1.6% (n=5)**
Unarmed fight	0	0	0	0	0	0	0.7% (n=1)	0	**0.3% (n=1)**
Non – trauma	0	0	1.7% (n=1)	0	0	6.7% (n=1)	1.5% (n=2)	9.5% (n=2)	**1.9% (n=6)**
Total Number	**0.3% (n=1)**	**0.6% (n=2)**	**17.8% (n=56)**	**7% (n=22)**	**19.7% (n=62)**	**4.8% (n=15)**	**43.2% (n=136)**	**6.7% (n=21)**	**315**

Table 4.1 Mechanism of injury of paediatric pre-hospital intubations between January 1st 2000 and October 30th 2011

RTC – Patient Designation	Total Patients
Motorcyclist	3.1% (n=6)
Motorcycle passenger	1.6% (n=3)
Driver	0.5% (n=1)
Passenger	8.4% (n=16)
Pedal cyclist	12.6% (n=24)
Pedestrian	73.3% (n=140)
Unknown	0.5% (n=1)
Total	**100% (n=191)**

Table 4.2 Designation of patients involved in road traffic crashes that received pre-hospital intubation

Analysis of mechanism of injury and intubation frequency demonstrated associations of varying degree occurring within sub-groups. Notably, the incidents most frequently attended and their intubation frequencies were as follows: RTCs (23.8%); 'falls from height' (10.7%); burns (6.4%) and penetrating trauma (5.9%). Relative risk of intervention, (either of RSI or intubation) is reported in Table 4.3. RTCs (most common mechanism of injury) were used as a reference point and given a relative risk of 1 to allow for comparative purposes.

Mechanism of Injury	Total Patients	RSI	Relative Risk (95% CI)	P value	Intubation	Relative Risk (95% CI)	P value
Road traffic crash	803	20.7% (n=166)	1 (Reference)	-	3.1% (n=25)	1 (Reference)	-
Accident involving machinery	3	0	0	0.999	33.3% (n=1)	12.26 (1.08 to 139.8)	0.044
Animal incident	31	3.2% (n=1)	0.12 (0.02 to 0.91)	0.041	0	0	0.993
Burns	157	6.4% (n=10)	0.25 (0.13 to 0.49)	<0.001	0	0	0.984
Drowning	49	10.2% (n=5)	0.55 (0.21 to 1.42)	0.214	20.4% (n=10)	7.21 (3.21 to 16.22)	0
Fall from height	546	9.2% (n=50)	0.38 (0.27 to 0.53)	<0.001	1.5% (n=8)	0.40 (0.18 to 0.90)	0.026
Hanging	13	15.4% (n=2)	1.24 (0.25 to 6.19)	0.794	38.5% (n=5)	20.44 (5.84 to 71.52)	0
Penetrating trauma	221	3.2% (n=7)	0.13 (0.06 to 0.27)	<0.001	2.7% (n=6)	0.71 (0.29 to 1.75)	0.453
Struck by object/ person	52	11.5% (n=6)	0.5 (0.21 to 1.18)	0.113	1.9% (n=1)	0.54 (0.07 to 4.11)	0.556
Suffocation	6	66.7% (n=4)	14.86 (1.65 to 133.85)	0.016	16.7% (n=1)	24.52 (1.49 to 403.43)	0.025
Unarmed fight	11	9.1% (n=1)	0.37 (0.05 to 2.92)	0.347	0	0	0.996
Non-trauma	19	15.8% (n=3)	0.86 (0.24 to 3.04)	0.812	15.8% (n=3)	5.66 (1.52 to 21.13)	0.01

Table 4.3 Relative risk of pre-hospital intubation by mechanism of injury

4.5 Intubation Success Rate

Intubation success was defined as correct placement of an endotracheal tube within two attempts at direct laryngoscopy. This was confirmed by colourimetry and digital capnography. Failure to achieve this was considered a 'failed intubation' and led to one of three pathways: placement of a supraglottic airway device, surgical airway or bag-valve-mask ventilation with transport to hospital.

During the study period, 95 doctors rotated through the service. Caseload range was 1 - 12 paediatric intubations per doctor. Of the 315 patients who received a pre-hospital intubation, one patient was classified as a failed intubation and was intubated only after arrival in hospital. In all other cases, the trachea was successfully intubated within two attempts when RSI or intubation was performed as per SOP. Despite the presence of laryngeal mask airways and equipment for cricothyroidotomy, neither was utilized in paediatric patients during this twelve year period.

The overall success rate was 99.7% for paediatric pre-hospital intubation in this service.

4.6 Scene time

The median scene time for patients that did not receive intervention was 20 minutes (interquartile range 12-28min). When an intubation was carried out, the median scene time was found to be 21.65 minutes (interquartile range 15.3 – 25);(Wilcoxon Rank Sum Test) for patients being intubated for near or actual cardiac arrest. The median scene time when RSI was delivered was 41.61 minutes (interquartile range 32 – 49); ($p<0.001$; Wilcoxon Rank Sum Test). The majority of patients (74.9%) were delivered to hospital within 60 minutes of the arrival of the operational team.

4.7 Summary

This chapter presented the findings of the study and provided a succinct description of the data.

Chapter Five

Discussion

5.1 Introduction

This 12 year retrospective observational study of paediatric anaesthesia and intubation in a high volume, doctor-led, pre-hospital trauma service reports on a previously understudied population of trauma patients. This chapter is directed to the discussion, interpretation and significance of these findings. It ensures that the original research questions have been answered and the aims of the study have been met.

5.2 Epidemiology of Paediatric Pre-hospital Intubation

It is important to understand the frequency with which difficult problems will be encountered in a system, particularly when designing training for EMS providers.[16] This study reveals that in a trauma service attending approximately 1500 patients a year only a small fraction are children. The proportion of children that require intubation accounts for less than ten percent of total intubations delivered and concurs with findings from other studies.[4,10,16-19]

The London Ambulance Service attended more than one million emergency calls in 2011/12.[17] In context, these results support the evidence that a very small, yet consistent number of critically injured children will be encountered by a targeted trauma service and is similar to the experience of another air ambulance service in

Germany.[4] Because this type of event is infrequent[5,8,14] it is likely only dedicated enhanced care teams will be able to develop cumulative system experience in these procedures. Even they are likely to require careful training to maintain skill levels.[4,16]

Although paediatric major trauma is uncommon it represents a significant proportion of paediatric deaths.[2-4] The finding that 20% of children were intubated without anaesthesia because they were either critically unstable or in cardiac arrest supports this. The remainder were alive and required RSI. Enhanced care teams require the skill-set, infrastructure, support services and on-going training to ensure that this standard of care is routinely available and deliverable.[4,6]

Inability to offer pre-hospital paediatric RSI would mean more than 80% of children requiring advanced airway management would have potentially received sub optimal care.[15] This is already an established concern.[4,19,20]

5.3 Demographic Observations

5.3.1 Age

An even breakdown of intubation frequency by age was found. Roughly a quarter of children intubated were 1-5 years, a quarter was 6-10 years and half were 11-15 years old. The increased frequency of intubations in older children is likely to be due to increased mobility and this trend is observed elsewhere.[2]

Further contribution may arise from: changes in seating position within motor vehicles; more relaxed approaches to vehicular restraint devices; increased numbers of children walking to school or riding bicycles; increased exposure to knife crime; truancy; or poor social circumstances. This is however speculative.

In contrast to Eich et al, very few children in the <1year age group were intubated for trauma (only 3 in over a decade). There are a number of possible explanations. Firstly, it could suggest that few infants sustain severe trauma, and would agree with the paediatric trauma patterns described by Bayreuther et al.[2]

The higher threshold for paediatric intubation may also be important in this very young age group. Given that basic airway management in small children is usually straightforward,[6,8] it could be that RSI was being deferred until the 'safer' in-hospital environment. Discussion with a pre-hospital specialist prior to undertaking RSI in this age group is strongly encouraged because it is known that the <1year age group is more difficult to intubate.[5]

It must be noted that the research is not directly comparable with other studies. In the study by Eich et al, the 7.5% incidence of pre-hospital intubation in the <1year age group included pre-hospital intubation of children suffering multiple medical and traumatic conditions (including respiratory illnesses which are known to be associated with higher intubation rates.)[4]

It is possible a combination of the above factors explains these inter-system differences in intubation rate. However further study is required.

5.3.2 Gender

Approximately two thirds of the cases attended were males. A similar proportion of the intubations delivered were also in males. This concurs with previously reported male to female injury profiles and their intubation rates.[2,5,22,31]

Obvious anecdotal and speculative inferences may be made about males and risk-taking behaviour, parental control, independence and gang related activity. Though there is currently little evidence to substantiate these assertions.

5.3.3 Time of Day

Paediatric intubations most commonly occur in the afternoon or early evening. In association with the high incidence of pedestrian and pedal cyclist incidents, this reflects the period when children leave school in large numbers and are in transit.[31] A small early morning peak in intubations may reflect transport related incidents while en-route to school.[31]

Intubations are rarely carried out at night after ten pm (1.25 per year) particularly in the younger age groups. This is likely because most young children spend their nights in bed. Such a finding could have implications in directing staffing in systems where there exists a shortage of skilled EMS providers.

The public health concerns surrounding transport incidents, cyclists, helmet use and education are not new.[31] The role of the current UK daylight saving policy in early evening accidents is controversial and the possibility of accident reduction by delaying twilight has been previously discussed.[32,33] Though an inverse relationship between light level and fatal RTC's (particularly for pedestrians and pedal cyclists) has been demonstrated[33] the precise effect this would have is difficult to determine without further local study.

5.4 Mechanism of Injury

Blunt trauma exceeds penetrating trauma in children.[2,22] Nearly 80% of children receiving RSI sustained either an RTC (60.8%) or a 'falls from height' (18.4%) which mirrored Bayreuther' observations on trauma aetiology.[2] Only 3.8% were victims of penetrating trauma. (Despite a noted rise in attendance at stabbing and shooting incidents by the LAA during the study).[34]

It is relevant that the dispatch criterion for the LAA team for 'falls from height' is that the victim has fallen 'greater than twenty feet or two floors'. Given the high volume of attendances but low intubation rates there is speculation that some children may be seen to fall from significant heights without sustaining injury severe enough to justify pre-hospital intubation.

Conversely nearly one in four children involved in an RTC will require intubation. It is notable that of these children 72.9% were pedestrians and 13% were pedal cyclists and lack the relative protection of a motor vehicle or restraint devices. This is a public health area that still requires determined intervention to improve yet may yield dramatic results if appropriately addressed.

Relative risks calculated for RSI with different injury mechanisms (as compared with RTCs) demonstrated 'falls from height' (0.38); burns (0.25) and penetrating trauma (0.13) had reduced risk for intubation. Conversely children suffering drowning (7.21), hanging (20.44) and suffocation (24.52) ('asphyxia-type' injuries) showed increased likelihood for intubation, though the absolute numbers of these events was so low that any conclusions should be guarded.

By their nature, these incidents are associated with a poor clinical state at presentation. The impairment of physiology (hypoxic injury, depressed levels of consciousness, cerebral irritation); and/ or likelihood of encountering the child in near or actual cardiac arrest at presentation; were anecdotally observed to frequently trigger the paediatric RSI SOP or need for immediate intubation and has been similarly observed elsewhere.[5]

5.5 Intubation Success

The reported 99.7% intubation success rate for pre-hospital paediatric intubation in this study compares very well with undifferentiated, doctor-delivered, pre-hospital intubation success rates.[5,11,12,21] Earlier studies reported highly variable success rates for pre-hospital intubation of children performed by paramedics or doctors.[3,18,21,24,28]

5.5.1 Operator Factors

Other systems, while not directly comparable with the LAA, have a number of significant differences in approach. Many (though not all) were paramedic based systems with varying degrees of training and experience.[11,21] Significant differences between doctor and paramedic intubation success rates have been reported.[5,11,12,21] This is thought (in part) to be a result of more frequent in-hospital exposure to intubations in general and therefore more accumulated experience.[27]

At the LAA the doctor performs the intubation in every case. The doctors are experienced anaesthetists or emergency physicians with anaesthesia training.

Breckwoldt has recently commented on the improved pre-hospital intubation success rates of 'expert' intubators rather than 'proficient' intubators.[27] LAA doctors are, by the definitions used in this paper, a mixture of the two (emergency physicians meeting the approximate experience levels of 'proficient' and anaesthetists 'expert').

The LAA serves a large population (up to 10 million) with one operational team and therefore has a large trauma throughput. Individual doctors may only be in post for six months but will conduct an average 150 trauma missions in this period and therefore might expect to attend approximately 20 children of which only 3 will require intubation. Thus around one paediatric intubation per month per doctor is likely. This volume would be considered high exposure to pre-hospital paediatric intubation as compared with other EMS systems.

5.5.2 Procedural Factors

Techniques for pre-hospital airway management have evolved in the last decade.[15] Early studies did not routinely perform RSI as the technique of choice for securing the airway and many did not routinely use muscle relaxants to perform intubation. The introduction of a prescriptive SOP defining the roles of the intubator/ assistant, the equipment used and the planning of the procedure has been associated with improved intubation success regardless of training background.[12] Furthermore it is recommended that a customised, locally established and stepwise approach to the management of the difficult or failed airway should be established in all systems performing paediatric airway management.[35]

At the LAA, RSI is the procedure of choice for pre-hospital intubation unless the patient is in cardiac arrest. A robust, routinely performed and regularly practiced SOP exists for RSI with defined roles, limited drug choices and a simple prescribed algorithm for encountered difficulty. (Appendix 2)

5.5.3 Training Factors

It is difficult to determine which (if any) element of experience, training or standard operating procedure has contributed to the high reported intubation success rate at the LAA. Nor is it known what form training or experience should take.[15,19,2127]

The LAA approach to this issue and other complex on-scene interventions is to ensure that procedures are made as reproducible as possible, with limited choices and are practiced often both clinically and in the simulation environment. Simulation-based medical education compliments clinical teaching and improves technical skills, non-technical skills, teamwork and performance during difficult airway management.[35,36]

Further study of the benefits of individual parts of this pathway might better quantify the most important elements, though the low number of paediatric cases may require extrapolation from manikin or other (adult) cases.

Paediatric supraglottic airway devices were introduced into the LAA system two thirds of the way through the study period. They have never been used but are present because the AAGBI pre-hospital anaesthesia guidelines[6] aim for the same standards of anaesthesia as practiced in-hospital. They are also recommended by the Difficult Airway Society Guidelines for the unexpected difficult airway in children.[35]

5.5.4 Patient Factors

The difficult paediatric airway, (defined as difficult mask ventilation and/or unsuccessful intubation) is rare.[35] The incidence of difficult airways encountered is higher in children <1year and diminishes progressively with advancing age (particularly above the age of 5 years) as anatomical differences become less apparent.[5,28,35]

Nearly three quarters of children intubated were between the ages of 5 and 16 years old and only three patients in the <1year age group received pre-hospital intubation. This low incidence may contribute to the observed high success rates as this difficult population is avoided. Intubation without anaesthesia was 100% successful. Both groups of patients were rendered apnoeic and flaccid allowing for identical and good intubating conditions.

In a single case (a 3 year old female, suffering 'falls from height', in respiratory arrest upon the arrival of the operational team) the trachea was unable to be successfully intubated after 2 attempts. Following the SOP, bag-valve-mask assisted ventilation maintained oxygen saturation at 95% and the patient was transferred to a trauma centre without further attempts at laryngoscopy. Further difficulty was encountered with intubation by the in-hospital team before this was ultimately achieved. From the case notes it is not readily determinable whether the difficulty was operator dependent or difficult anatomy related to age and size. It does not appear that equipment failure played a role. The patient subsequently died from her injuries. Without further information it is impossible to speculate on the factors responsible for difficulty in this case. However number of attempts at laryngoscopy may be relevant. It is possible a more liberal SOP may have resulted in a different outcome. This however is purely speculation.

The LAA believe that the high intubation success rates may be contributed too by delivering pre-hospital intubation as a packaged 'bundle of care' which combines the following factors: accumulated service experience; doctor seniority; training and simulation; intubation threshold; advanced age of majority of children intubated (>5years); and the relative ease of intubation of most anatomically normal paediatric airways.

5.6 Scene Time

A median scene time of 20 minutes increasing to 41 minutes when RSI was delivered is thought to be consistent with other services delivering pre-hospital RSI.[5,13] The increased scene time may reflect sicker patients in the RSI group requiring multiple interventions. The LAA database does not collect markers of injury severity and without this data it is impossible to comment further.

The LAA supports the concept of 'time to critical intervention'.[13,18] Conducting pre-hospital 'critical interventions' might expedite emergency department throughput.[13]

The LAA have noted that patients who arrive in the emergency department already intubated have very short emergency department times and go to the operating theatre or the Computed Tomography (CT) scanner very quickly. (Anecdotal, personal communication – Medical Director LAA) Some even bypass the emergency department and go directly to CT scanner depending on local protocol. Scene time spent performing 'critical interventions', has been shown to be recouped by reduced in-hospital time.[13] Investigation of this phenomenon was not an aim of this study nor was this data available on the database.

For children in near or actual cardiac arrest, scene times may be shorter as a result of a minimum of interventions being delivered with rapid hospital transport being the goal. This rationale underlies a reluctance to terminate resuscitation outside hospital in young, healthy physiology that may respond to resuscitation with blood products and other in-hospital adjuncts not readily available on the roadside.

The contrast between RSI versus intubation without anaesthesia is in the time taken to conduct the procedure. Preparation for RSI may take some minutes. The SOP ensures that the procedure is conducted smoothly, without risk and following thorough preparation for all eventualities. (Appendix 2) In the patient in extremis or cardiac arrest, immediate oxygenation is vital. No drug therapy is required. Preparation, checklist use and equipment are reduced to essentials. (Appendix 2) Any further therapy other than high quality chest compressions is undertaken in transit to hospital. The negligible difference between pre-hospital intubation and no intervention reflects this minimalist approach.

Transit times to any of the four major trauma centres in London are typically short and 74.9% percent of the patients were within a specialist centre within 60 minutes of the operational team arriving at the incident. This could be considered a key performance indicator.

5.7 Summary

The landscape of pre-hospital paediatric intubation has been described. This chapter has discussed the significance and relevance of the findings of the study. A clear picture of the nature of the environment and framework within which the LAA interacts with paediatric trauma has emerged. The demographic profile has been described and the mechanisms of injury been explored. There has been a discussion about possible reasons behind the high success rate of paediatric pre-hospital RSI and intubation. Lastly the implication of the scene time data was explored.

Chapter Six

Conclusion

6.1 Conclusion

While paediatric trauma makes up only a small proportion of the overall trauma burden, the requirement for pre-hospital paediatric intubation in those attended by a targeted trauma service is not infrequent. The majority of patients receive an RSI for intubation, while the minority are intubated without anaesthesia for near or actual cardiac arrest. The bulk of interventions are carried out in the daytime (afternoon or early evening) on male, school-going aged victims of RTC's or 'falls from height'. Although associated with appropriately longer scene times, it appears the intervention is necessary and relevant in a small number of critically injured children. Despite limited exposures for individual doctors, pre-hospital paediatric intubation success rates are high in the service studied.

6.2 Limitations

The study was limited by its retrospective, observational and contextual nature.

In retrospective studies, the integrity of the data is dependent on accurate reporting by clinicians and completed entries into the database. Failure to capture patients or specific patient details may have led to reporting bias. The patient report form (Appendix 4) has fixed fields which limited data available for investigation. These data fields were pre-determined.

Data sets that may have been desirable for study include: the number of attempts at laryngoscopy during pre-hospital intubation; difficulties encountered or complications occurring during or after the procedure; injury severity markers.

Low reported numbers of certain mechanisms of injury make it difficult to draw substantial conclusions about trauma subtypes and their relationship to pre-hospital intubation. Though calculated relative risks suggest this may be an area of further interest.

Due to the nature of the clinical environment and the current process for recording relevant time intervals, the scene time is a gross estimate and likely an inaccurate reflection of true scene time. Because scene time and outcomes are related, interpretation and conclusions based on scene time findings should be guarded. Lack of data on injury severity and time spent in the emergency department limits interpretation of scene times in terms of this. Therefore the relationship between scene-time, in-hospital time and injury severity remains unexplored in this system.

The contextual nature of the study and the heterogeneous nature of the pre-hospital literature limit the generalizability of the results. The study evaluated local epidemiological data in a major metropolitan city and thus the results are specific to the investigated environment. There are also few targeted services dedicated exclusively to the management of pre-hospital trauma and the findings are difficult to compare or apply broadly to other EMS systems

Conversely in dedicated trauma services success rates may be higher because of the trends of increasing trauma with age and the association with intubation success and advancing age. This may introduce selection bias.

A minor documentation and reporting limitation is the graphical depiction of the times of day of intubation, which reflect the intubations that took place per sixty minute period and do not reflect the exact time the intubation took place. This was necessary for ease of reporting but could lead to potential imprecision.

6.3 Implications & Future Research

As a result of a paucity of epidemiological research on this patient group, little has been known about this population until now. This is likely because few pre-hospital systems that offer doctor-led targeted trauma care see sufficient volumes of paediatric trauma to generate a meaningful body of data. The LAA has taken over a decade to accumulate this case series of less than five hundred patients.

Serious paediatric trauma is uncommon, however a sufficient population of patients requiring pre-hospital paediatric intubation exists and energy must be directed at ensuring knowledge, skill and ability exists within a targeted trauma service to be able to safely and effectively deliver this care when required.

Based on the epidemiological findings, shift and staff planning could be directed to ensure this capability exists at certain time periods in services where resource constraints are problematic. Importantly out of hours shift patterns could expect to encounter a minimum of patients.

Social initiatives with respect to: pedestrian and cycle safety; helmet wear; and safety measures in structures higher than a single storey; are likely to have greater impact on overall burden of disease than any interventions that may be delivered by the EMS. Daylight saving initiatives could have genuine impact on the burden of paediatric trauma.

A significant finding is the high success rate for the procedure. This is important for EMS providers who deliver pre-hospital intubation to know. Anxiety related to delivering this procedure in children may be tempered with the knowledge that the majority of these patients will be above the age of five years (older and easier) and that the technique is frequently successful.

Quantifying the scene time more accurately would its use as a key performance indicator and the direction of training modules to make further reductions.

A major source of controversy in this particular field of research is the relationship between pre-hospital paediatric intubation and outcome. This data was not recorded within the database and therefore this relationship has not been explored. It is a key area for further study.

Future research is likely to prove difficult as a result of the small volumes of patients encountered. Prospective research will allow refinement of data collection tools and the establishment of more targeted clinical questions. Potential areas that could be explored that have arisen as new clinical questions from this study include the following:

- What exactly is occurring in the <1year age group?
- What would be the impact on paediatric trauma if different daylight saving initiatives were instituted?
- What is occurring in the 'falls from height' group where large numbers of patients fall from significant heights but appear to avoid critical injury?

6.4 Summary

This chapter concludes the research report and succinctly describes the overall conclusion of the study. There is a discussion of the study limitations, implications and suggestions for future research.

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Appendix 1

G Model
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Clinical paper

An observational study of paediatric pre-hospital intubation and anaesthesia in 1933 children attended by a physician-led, pre-hospital trauma service

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ABSTRACT

Introduction: Trauma accounts for 16–44% of childhood deaths. The number of severely injured children who require pre-hospital advanced airway intervention is thought to be small but there is little published data detailing the epidemiology of these interventions. This study was designed to evaluate the children who received pre-hospital intubation (with or without anaesthesia) in a high volume, physician-led, pre-hospital trauma service and the circumstances surrounding the intervention.
Methods: We conducted a 12 year retrospective database analysis of paediatric patients attended by a United Kingdom, physician-led, pre-hospital trauma service. All paediatric patients (<16 years of age) that were attended and received pre-hospital advanced airway intervention were included. The total number of pre-hospital intubations and the proportion that received a rapid sequence induction (RSI) were established. To illustrate the context of these interventions the ages, injury mechanisms and intervention success rates were recorded.
Results: Between 1 January 2000 and 31 October 2011 the service attended 1933 children. There were 315 (16.3%) pre-hospital intubations. Of those intubated, 81% received a rapid sequence induction and 19% were intubated without anaesthesia in the setting of near or actual cardiac arrest. Nearly three quarters of the patients were in the age range of 6–15 years with only 3 patients under the age of 1 year. The most common injury mechanisms that required intubation were Road Traffic Crashes (RTC) and 'falls from height'. These accounted for 79% of patients receiving intubation. Intubation success rate was 99.7% with a single failed intubation during the study period.
Conclusion: Pre-hospital paediatric intubation is not infrequent in this high-volume trauma service. The majority of patients received a rapid sequence induction. The commonest injury mechanisms were RTCs and 'falls from height'. Pre-hospital paediatric intubation is associated with a high success rate in this physician-led service.

1. Introduction

Trauma accounts for a large proportion of childhood mortality and is the leading cause of death in those aged 1–44 years.[1–3] Despite this, the exposure of individual emergency responders to severely injured children is relatively infrequent.[3,4]

Although airway and ventilation problems have been identified as key issues in severely injured patients, few children sustain injuries severe enough to require pre-hospital tracheal intubation and anaesthesia.[1,3–4] Furthermore, several studies have suggested that simple airway manoeuvres are usually adequate to treat early airway compromise in children.[6,8]

The perception that pre-hospital paediatric Rapid Sequence Induction (RSI) of anaesthesia is rarely required and challenging to deliver safely,[2,6] may contribute to the scarcity of publications on the subject. A safety guideline published by the Association of Anaesthetists of Great Britain and Ireland (AAGBI) recommends that pre-hospital anaesthesia in children should only be performed by a skilled, anaesthetic-trained practitioner, where simple airway manoeuvres and oxygen therapy have failed to provide a patent airway and adequate oxygenation.[6] The guideline suggests that even in relatively advanced systems, the threshold for pre-hospital paediatric intubation and anaesthesia should be relatively high.[6] However, it is likely that in a small number of patients intubation is required to provide and maintain a definitive airway and can

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be lifesaving in critically injured children if delivered rapidly and safely.

Recent studies in the United Kingdom (UK) have identified a lack of comprehensive data on advanced airway management, particularly pre-hospital anaesthesia in acutely injured children. Although several studies have addressed pre-hospital airway management in adults, trauma patterns in children and pre-hospital interventions in children, few have specifically evaluated pre-hospital paediatric intubation and anaesthesia. This may be because few services attend sufficiently high numbers of paediatric trauma patients to accumulate meaningful samples of patients to report. The lack of published data on this subject has stimulated various authorities to suggest that this subject is a priority area in pre-hospital research.

This study was therefore conducted to report on key issues surrounding paediatric pre-hospital intubation and anaesthesia in the setting of a high volume, pre-hospital trauma service and to answer the following questions:

- What is the frequency of paediatric pre-hospital intubation in a high volume trauma service?
- How many children who were intubated received an RSI and how many were intubated without drugs?
- What is the demographic profile of children who receive pre-hospital intubation?
- Are the interventions required at particular times of the day?
- Which injury mechanisms are commonly associated with paediatric intubation?
- What are the on-scene times when children receive intubation?
- What is the pre-hospital intubation success rate in a high volume, physician-led service?

2. Methods

2.1. Study setting

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.[11]

The study was carried out in an urban, physician-led, pre-hospital trauma service, serving a daytime population of up to 10 million people in an area approximately 5000 km^2.

The operational team (doctor and paramedic) is delivered to incidents by helicopter in the daytime and by fast response car at night. Tasking is by flight paramedics who are stationed in the ambulance control room and only dispatch the service to trauma patients, specifically those with severe injury. This allows seamless integration with the ambulance service from a tasking and operational perspective. As a result, access to the service is straightforward and early requests are made from the ground ambulances. Deployment is rapid and flight times across London are short. Consequently many injured patients are accessed by the service that might otherwise have been taken to local hospitals. The operational team are always dispatched in addition to the standard land ambulance response. The service attends an average of 5–6 trauma patients per day.

Scene time is logged by the control room when the helicopter lands on the ground or the rapid response vehicle arrives at the incident. Departure from the scene is similarly radioed to the control room when the transport vehicle (land ambulance or helicopter) departs carrying the patient. This entire time period (encompassing de-bussing from the vehicle, transport to the actual incident from the helicopter landing site, handover from the ground crew, extrication (as necessary), patient assessment, treatment, intubation (RSI, packaging and loading) constitutes the recorded scene time. It is thus a gross estimate of total time on the scene and an inaccurate reflection of time spent actually delivering medical care or performance of medical procedures.

Triage decision-making is the responsibility of the operational team. Patients are delivered direct to specialist centres as appropriate thus avoiding delays to definitive treatment and lengthy secondary transfer times. Secondary transfer rates for patients attended by the service are typically extremely low.

Doctors are experienced anaesthetists or emergency physicians with a minimum of 6 months of in-hospital anaesthetic experience. Most doctors have some prior pre-hospital training and experience. Further in post training is provided in a 4–6 week induction period under the guidance and supervision of pre-hospital care consultants. Weekly case review, audit and clinical governance meetings and intermittent consultant supervision ensures consistency with service protocols and maintenance of service standards. Flight paramedics have specific in service training to equip them as members of the pre-hospital anaesthesia team.

Pre-hospital anaesthesia is carried out in line with UK recommendations on pre-hospital anaesthesia[6] and according to local standard operating procedures (SOP). Indications for pre-hospital RSI are (1) actual or impending airway compromise; (2) ventilatory failure; (3) unconsciousness or profound cerebral agitation; (4) anticipated clinical course; and (5) humanitarian reasons. The local service SOP for RSI is robust and has been practiced for over 10 years. It has seen the performance of over 2000 pre-hospital RSIs with a high intubation success rate.[14] A standardised and reproducible anaesthetic technique is used and the on-scene doctor has a limited number of treatment choices to make. In the study period etomidate was used to induce anaesthesia and suxamethonium was used for initial muscle relaxation. Intubation is carried out by the doctor with the routine use of an intubating catheter (Cook Medical Frova airway intubating catheter™). When patients are in established or impending cardiac arrest intubation is conducted without drug assistance. Equipment for failed intubation includes a supraglottic airway device and equipment for surgical cricothyroidotomy. Correct tube placement is confirmed by the use of colourimetry and digital capnography. A mechanical ventilator is available to ventilate patients after intubation (Drager Oxylog 2000™).

The SOP allows for a maximum of two initial attempts at intubation after drug administration. A set of operator drills to improve laryngoscopy when difficulty is encountered are followed if there is failure at the first attempt. Further failure to intubate leads the practitioner down a pathway to either placement of a supraglottic device (laryngeal mask airway) or a surgical airway. A third alternative (bag-valve-mask ventilation while transport to hospital is conducted) exists for patients in whom a surgical airway is undesirable or impossible. At least two good attempts at intubation must be performed. All members of the service are drilled in the procedure and regularly practice in a low fidelity simulation environment. In keeping with the AAGBI guidelines, the SOP emphasizes that the threshold for paediatric anaesthesia is higher than that for adult pre-hospital anaesthesia and only be conducted when absolutely necessary.[6] Where possible, prior to performing paediatric anaesthesia, the decision is discussed with an on-call consultant. This is to discuss equivocal cases or to assist with determining risk/benefit analysis where the risk is felt to be extremely high or the benefit to be limited. This aspect of clinical governance and oversight is felt to be desirable when on-scene conditions are especially challenging.

2.2. Study design

Standard patient data on patients attended by the service is prospectively recorded on a Microsoft ACCESS™ database by the

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attending pre-hospital physician. A retrospective database review was conducted on patients attended between 1 January 2000 and 31 October 2011. This study involved analysis of the accumulated standard system data. No additional data were collected for this study and no additional interventions carried out. The project was therefore registered as a hospital service evaluation.

Inclusion criteria were all patients attended by the service under the age of 16 years. Patient demographics and mechanism of injury were recorded. Mission reports (standardised pro forma) of every case of pre-hospital anaesthesia and intubation were then evaluated to look for additional detail including complications or failed intubations. Statistical analysis was applied using multinomial logistic regression. Relative risks and 95% confidence intervals were calculated and where appropriate additional statistical testing (Wilcoxon Rank Sum Test) was used to report medians and interquartile ranges. Statistical significance of data, where relevant, was reported. Statistical analysis was performed in Microsoft Excel™ and STATA v12.

3. Results

During the study period from January 1st 2000 to October 31st 2011 a total of 14,716 trauma patients were attended and 3509 (23.8%) received pre-hospital intubation. 1933 (13.1%) of the patients attended were children (<16 years of age). 315 (9% of the total pre-hospital intubations) were carried out on children accounting for 16.3% of paediatric patient attendances. Of these, 255 (81%) of the paediatric patients received an RSI and 60 (19%) were intubated without anaesthesia. The intubation success rate was 99.7% (one failed intubation out of 315) (Fig. 1).

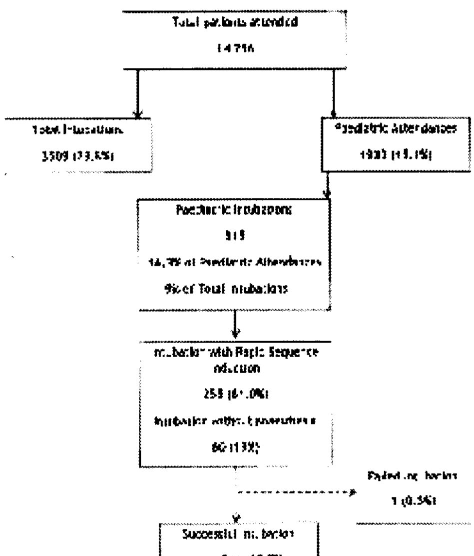

Fig. 1. Schematic of pre-hospital critical interventions during 1 January 2000 to 31 October 2011.

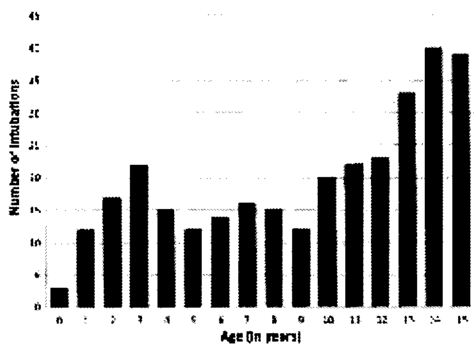

Fig. 2. Graph to show frequency of pre-hospital intubation by age.

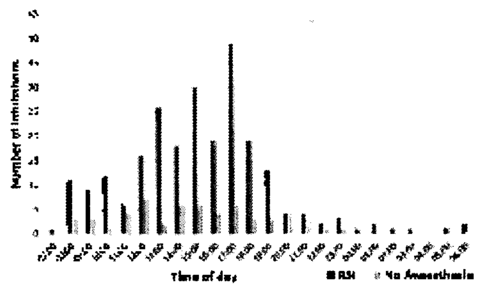

Fig. 3. Graph to show frequency of paediatric intubation by time of day.

3.1. Demographics

From the total 1933 patients, 1333 (69%) were male and 600 (31%) were female, 57 (2.9%) children under the age of 1 year were attended. Of the children receiving pre-hospital intubation 209 (66.3%) were male and 106 (33.7%) were female. The median age was 10 years. 3 children (1%) were under the age of 1 year, 78 (24.8%) were aged 1–5 years, 77 (24.4%) were aged 6–10 years and 157 (49.8%) were aged 11–15 years (Fig. 2).

3.2. Time of day

Data on intubation time of day was only available for 297 patients. The frequency of pre-hospital intubation was observed to vary with time of day. A peak occurred between the times of 12:00 and 14:00 and a second greater peak occurred between 15:00 and 18:00. Few paediatric intubations (15 in total) occurred after 22:00 (Fig. 3).

3.3. Mechanism of injury

All patients had a clearly identified mechanism of injury in the database. 309 sustained traumatic injuries and 6 patients turned out to not be victims of trauma. Table 1 shows the mechanism of injury for all patients who received a pre-hospital intubation. Blunt trauma accounted for the majority requiring intubation with road traffic crashes (RTCs) and 'falls from height' accounting for 60.5% (n = 191) and 18.5% (n = 58), respectively.

Table 1
Mechanism of injury for all paediatric pre-hospital intubations.

Mechanism of injury	<1 year		1–5 years		5–10 years		11–15 years		Total
	RSI	No anaesthesia	RSI	No anaesthesia	RSI	No anaesthesia	RSI	No anaesthesia	
Accidents involving machinery	0	0	0	4.5% (n = 1)	0	0	0	0	0.3% (n = 1)
Animal incident	0	0	0	0	0	0	0.7% (n = 1)	0	0.3% (n = 1)
Burns	0	0	8.9% (n = 5)	0	1.6% (n = 1)	0	0.9% (n = 1)	0	3.2% (n = 10)
Drowning	0	0	3.5% (n = 2)	27.3% (n = 6)	3.2% (n = 2)	6.7% (n = 1)	0.7% (n = 1)	14.3% (n = 3)	4.8% (n = 15)
Fall from height	0	100% (n = 2)	44.6% (n = 25)	4.5% (n = 1)	16.1% (n = 10)	13.3% (n = 2)	11.1% (n = 12)	14.3% (n = 3)	17.8% (n = 56)
Hanging	0	0	0	4.5% (n = 1)	0	6.7% (n = 1)	1.5% (n = 2)	14.3% (n = 3)	2.2% (n = 7)
Penetrating trauma	0	0	1.7% (n = 1)	4.5% (n = 1)	0	13.3% (n = 2)	4.4% (n = 6)	14.3% (n = 3)	4.1% (n = 13)
Road traffic crash	0	0	37.5% (n = 21)	50% (n = 11)	79.0% (n = 49)	46.7% (n = 7)	70.4% (n = 95)	33.3% (n = 7)	60.6% (n = 191)
Struck by object/person	100% (n = 1)	0	1.7% (n = 1)	0	0	6.7% (n = 1)	3.0% (n = 4)	0	2.2% (n = 7)
Suffocation	0	0	0	4.5% (n = 1)	0	0	3.0% (n = 4)	0	1.6% (n = 5)
Unarmed fight	0	0	0	0	0	0	0.7% (n = 1)	0	0.3% (n = 1)
Non trauma	0	0	1.7% (n = 1)	0	0	6.7% (n = 1)	1.5% (n = 2)	9.5% (n = 2)	1.9% (n = 6)
Total Number	1	2	56	22	62	15	116	21	315

Table 2
Designation of patients involved in road traffic crashes that receive intubation.

RTC – patient designation	Total patients
Motorcyclist	[illegible]
Motorcycle pillion	1.0% (n = [illegible])
Driver	0.5% (n = 1)
Passenger	8.4% (n = 16)
Pedal cyclist	12.6% (n = 24)
Pedestrian	73.3% (n = 140)
Unknown	0.5% (n = 1)
Total	100% (n = 191)

More detailed evaluation of children involved in RTCs demonstrated the majority of these patients were either pedestrians struck by vehicles (73.3%) or pedal cyclists (12.6%). One child was the driver of a motor vehicle (Table 2).

Data cross referenced with mechanism of injury and intubation frequency demonstrated associations occurring within specific sub-groups. Notably, the incidents most frequently attended and their intubation incidences were as follows: RTCs (23.8%); 'falls from height' (10.7%); penetrating trauma (5.9%) and burns (6.4%). Relative risk of intubation (either by RSI or without anaesthesia) is reported. RTCs (most common mechanism of injury) are used as a reference point for comparison (Table 3).

3.4. Scene time

For paediatric attendances, median scene time for patients that did not receive intubation was 20 min (interquartile range 12–26 min). When the intervention was carried out, the median scene time was found to be 21.65 min (median 19.5, interquartile range 15.3–25; p < 0.001; Wilcoxon Rank Sum Test) for patients being intubated for near or actual cardiac arrest (no anaesthesia). The median scene time when RSI was delivered was 41.81 min (median 40, interquartile range 33–49, p < 0.001; Wilcoxon Rank Sum Test). 74.9% of patients were recorded as having been delivered to hospital within 60 min of the arrival of the operational team.

3.5. Failed intubation

During the study period, 95 doctors rotated through the service. Caseload range was 1–12 paediatric intubations per doctor. Of the 315 patients who received a pre-hospital intubation, one patient was classified as a failed intubation and was intubated only after arrival in hospital. In all other cases, the trachea was successfully intubated within two attempts when RSI was performed. Despite the presence of laryngeal mask airways and equipment for cricothyroidotomy, neither was utilised in paediatric patients during this twelve year period. In this single case (a 3 year old, suffering a 'fall from height', in respiratory arrest upon the arrival of the operational team) the trachea was unable to be successfully intubated after 2 attempts. Following the standard operating procedure, bag-valve-mask assisted ventilation maintained oxygen saturation at 95% and the patient was transferred to a trauma centre without further attempts at laryngoscopy. Further difficulty was encountered with intubation by the in hospital team and the patient subsequently died from her injuries. The overall success rate was 99.7% for paediatric pre-hospital intubation in this service.

4. Discussion

This 12 year retrospective study of paediatric intubation and anaesthesia in a high volume physician-led, pre-hospital trauma service reports on a previously understudied population of trauma patients.

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Table 1
Relative risk of intubation by mechanism of injury.

Mechanism of injury	Total patients	RSI	Relative risk (95% CI)	p-Value	No anaesthesia	Relative risk (95% CI)
Road traffic crash	[illegible]	20.74 (n = 63)	1 (Reference)		1.59 (n = 25)	1 (Reference)
Accident involving machinery	1	0	0	0.993	[illegible] (n = 1)	[illegible]
Animal incident	[illegible]	3.23 (n = 1)	0.12 (0.02–0.91)	0.041	0	0
Burns	152	6.58 (n = 10)	0.25 (0.13–0.49)	<0.001	0	0
Drowning	[illegible]	[illegible]	0.55 (0.21–1.42)	0.214	[illegible]	7.21 [illegible]
Fall from height	[illegible]	[illegible] (n = 50)	0.38 (0.27–0.53)	<0.001	[illegible]	[illegible]
Hanging	13	15.38 (n = 2)	1.24 (0.25–6.19)	0.794	38.5 (n = 5)	20.44 (5.84–71.52)
Penetrating trauma	221	3.2 (n = 7)	[illegible]	<0.001	2.7% (n = 6)	0.71 (0.29–1.75)
Struck by object/person	52	11.54 (n = 6)	[illegible]	0.113	1.9% (n = 1)	[illegible]
Suffocation	6	[illegible]	[illegible]	[illegible]	16.7% (n = 1)	24.52 (1.48–405.4)
Unknown fall	11	9.1% (n = 1)	[illegible]	[illegible]	0	0
Non trauma	19	15.79 (n = 3)	[illegible]	0.812	15.8% (n = 3)	[illegible]

It is important to understand the frequency with which difficult problems will be encountered, particularly when designing training for Emergency Medical Services (EMS) responders. This study revealed that in a trauma service which attended approximately 1500 patients a year only 13.1% of these were children. Accordingly, the proportion of children that required intubation accounted for less than ten percent of total intubations delivered. The London ambulance service attended more than one million emergency calls in 2011/2012.[?] This suggests that a very small yet consistent number of severely injured children will be encountered by a targeted trauma service. Though in the greater context of the whole EMS this type of event is fortunately, relatively rare.[?] This does support the concept that only targeted enhanced care teams are likely to be able to develop adequate system experience in these uncommon events, but even they are likely to require careful training to maintain skill levels.

Although paediatric major trauma is uncommon it does happen regularly in a large population and represents a large proportion of paediatric deaths. Twenty percent of children intubated are either so critically unstable or in traumatic cardiac arrest that they do not receive anaesthesia prior to intubation. In keeping with other UK trauma data,[?] many of these critically unwell children sustained high energy blunt traumatic injuries (RTCs or falls from height) or asphyxia type injuries (drowning, hanging, suffocation). Intubation success rate was 100% in this group and not statistically different from the RSI group. Both groups are rendered apnoeic and flaccid allowing for identical and good intubating conditions.

Review of the patient demographics reveals that in keeping with the fact that around 2/3 of the cases attended were boys a similar proportion of the intubations required were also in boys. These data are consistent with previously reported male:female injury profiles and their intubation rates.[?] Notably, very few children under the age of a year were intubated for trauma (only 3 in over a decade). This is comforting and suggests that few infants sustain severe trauma, consistent with the paediatric trauma patterns described by Beyreuther et al.[1] This low figure, however, could also be attributed to a high threshold for paediatric intubation in this very young age group and/or the fact that basic airway management in small children is usually straightforward with the procedure of RSI being deferred until the 'safer' in hospital environment. The increased number of intubations carried out in older children is likely to be attributed to mobility and activities undertaken at different ages with increased opportunity for older children to be exposed to the risk of trauma.[1] Changes in seating position within a motor vehicle, for example, more relaxed approaches to vehicular restraint devices, increased numbers of children walking to school or riding bicycles and increased exposure to knife crime, truancy and poor social circumstances may further contribute.

Paediatric intubations most commonly occur in the afternoon. In association with the high incidence of pedestrian and pedal cyclist incidents, this reflects the period when children leave school in large numbers and are in transit.[?] A small early morning peak in intubations may reflect transport related incidents while en-route to school. Intubations are rarely carried out at night particularly in the younger age groups. This is likely to be because most young children spend their nights in bed. The public health concerns surrounding transport incidents, cyclists, helmet use and education are not new. The role of the current UK daylight saving policy in early evening accidents is controversial and the possibility of accident reduction by ensuring that there is more daylight later in the day has been previously discussed.[?] The precise effect this would have is difficult to determine.

Consistent with UK trauma epidemiology, blunt trauma far outweighs penetrating trauma in children.[?] Nearly 80% of children receiving RSI sustained either an RTC (60.8%) or a fall from height (18.4%). Only 3.8% were victims of penetrating trauma (despite a persistent rise in attendance at stabbing and shooting incidents by the service over the period).[?] It is relevant that the dispatch criterion for the operational team for 'fall from height' is that the victim has fallen 'greater than twenty feet or two floors'. Given the high volume of attendances but low intubation rates it appears possible that many children are seen to fall from significant heights without sustaining severe injury. Conversely it is unsurprising that nearly one in four children involved in an RTC will require intubation when it is noted that of these children 72.9% were pedestrians and 13% were pedal cyclists. This is a public health area that still requires determined intervention to improve.

Relative risks calculated for RSI with different injury mechanisms (as compared with RTCs) demonstrated 'falls from height' (0.38), burns (0.25) and penetrating trauma (0.13) had reduced risk for intubation. Conversely children suffering drowning (7.21), hanging (20.44) and suffocation (24.52) showed increased likelihood for intubation, though the frequency of these events was low. These are incidents, however, which by their nature are associated with a poor clinical state at presentation. The impairment of physiology (hypoxic injury, depressed levels of consciousness, cerebral irritation) and/or likelihood of encountering the child in near or actual cardiac arrest at presentation appears to frequently trigger the paediatric RSI SOP or need for immediate intubation.

A median scene time of 20 min increasing to 41 min when RSI is delivered is thought to be consistent with other services delivering pre hospital RSI. The increased scene time may reflect the possibility that the RSI group contained more patients with multiple injuries who required multiple interventions in addition to RSI. In addition to scene time our service aims to minimise the time to critical intervention, which may be carried out on scene or in hospital. We have noted that patients who arrive in the emergency department already intubated often have very short emergency department times and go to theatre or the CT scanner very quickly. Some even bypass the emergency department and go directly to CT scan. For children in near or actual cardiac arrest, scene times may be shorter as a result of a minimum of interventions being delivered with rapid expeditious hospital transport being the focus of the care-plan. This is the rationale of standard operating procedures and reluctance to terminate resuscitation outside hospital in young, healthy physiology that may respond to resuscitation with blood products and other in-hospital adjuncts not readily available on the roadside.

Transit times to any of the four major trauma centres in London are typically short and 74.9% of the patients were within a specialist centre within 60 min of the operational team arriving at the incident. A limitation of interpretation of the importance of scene times in this study is that they do not reflect only the time the operational team spends treating the patient. As mentioned the time period recorded here may encompass multiple aspects of the incident including transport to the incident from the helicopter landing site, access to the patient and extrication.

The difficulties of advanced airway management of injured children in the pre-hospital phase are influenced by the (in)frequency of the event and the potentially less controlled environment. The often emotionally charged scene and the presence of distressed relatives may contribute further challenges. It is readily accepted, however, that paediatric airway management is generally anatomically straightforward in the absence of congenital abnormalities.

The quality, safety and success of RSI and intubation may be related to the skill and experience of the personnel performing the procedure.[-,24] There are considerable variations in the training, experience and on-going patient exposure of EMS responders in different pre-hospital systems.[11] Higher complication rates have been reported when children are intubated by less experienced responders.[2] Gerritse reported a high incidence of complications in children intubated by paramedics, recommending that paramedics use bag-valve-mask techniques in the pre-hospital setting before a physician arrives at the scene.[7] Significant differences between physician and paramedic intubation success rates have been reported in adults.[15] In our service the doctor performs the intubation procedure in every case.

The reported 99.7% intubation success rate for paediatric pre-hospital intubation in this study compares very well with undifferentiated physician pre-hospital intubation success rates reported in a recent meta-analysis.[6] Other studies report success rates between 50% and 95% for pre-hospital intubation of children performed by paramedics or doctors.[-,-,25,26] It is thought that the high intubation success rates may also be contributed by the following factors: service experience; doctor seniority; training and simulation; intubation threshold and the relative ease of intubation of most anatomically normal paediatric airways. In addition, nearly three quarters of children intubated were between the ages of 5 and 15 years old, the significant anatomical differences in the paediatric airway rapidly diminishing with advancing age.

This service serves a large population (up to 10 million) with one operational team and therefore has a large trauma throughput. However, individual doctors may only be in post for six months and if they carry out an average 150 trauma missions in this period they might expect to attend approximately 20 children of which only 3 will require intubation. The previous experience and training in the system is likely to be important, since even in a high throughput system, one paediatric intubation a month per doctor is likely. Breckwoldt has recently commented on the improved pre-hospital intubation success rates of 'expert' intubators rather than 'proficient' intubators.[-] Our doctors are, by the definitions used in this paper, a mixture of the two (emergency physicians meeting the approximate experience levels of 'proficient' and anaesthetists 'expert'). We can not be sure which (if any) element of experience, training or standard operating procedure has contributed to our high reported intubation success rate in children. Our approach to this and other complex on-scene interventions, which we believe contributes to success, is that interventions are made as reproducible as possible with few choices and practiced often both clinically and in the simulation environment. Examples of this are well-defined team roles, limited choices of drugs and routine use of an intubating catheter. Further investigation of the benefits of individual parts of this pathway might better identify the most important elements, though the low number of paediatric cases may require extrapolation from similar or other (adult) cases.

Paediatric supraglottic airways were introduced into this system two thirds of the way through the study period. They have never been used but are present because we and the AAGBI pre-hospital anaesthesia guidelines[3] aim for the same standards of anaesthesia as practiced in the hospital emergency department. Paediatric supraglottic airways are always available in emergency department practice.

4.1. Limitations

Limitations of this study are similar to limitations imposed by all retrospective database studies. Results are dependent on accurate reporting by clinicians and complete entry into the database. Therefore complications not recorded by clinicians may have led to their under-reporting. We do not have reliable information on the difficulties encountered or number of intubation attempts made in each case only intubation success. Outcome data are not recorded within the database and therefore the relationship between RSI/intubation and outcome has not been explored in this paper.

5. Conclusions

While paediatric major trauma makes up only a small proportion of overall trauma workload, the requirement for pre-hospital paediatric intubation in those attended by a targeted trauma service is not infrequent. The majority of patients receive a rapid sequence induction for intubation, while the minority are intubated without anaesthesia for near or actual traumatic cardiac arrest. The bulk of interventions are carried out in the daytime or early evening on male, school-going aged victims of RTCs and 'falls from height'. Although associated with longer scene times we believe the intervention is necessary in a small number of critically injured children. Despite limited exposure for individual doctors pre-hospital paediatric intubation success rates in this service are high.

Conflicts of interest statement

None declared.

Acknowledgements

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Appendix 2

LONDON'S
AIR AMBULANCE

Pre-hospital Care Standard Operating Procedure

Rapid Sequence Intubation [RSI]

REVIEW:	May 2010	
APPROVAL/ ADOPTED:	PHC Policy Board	
DISTRIBUTION:	PHC Doctors PHC Paramedics	
RELATED DOCUMENTS:	SOP Scene Safety	
THIS DOCUMENT REFERS TO:	☑ PHC Clinical Practice PHC Non-clinical Practice PHC Operational Procedure	Ref: CP-8

Aims:

- Define indications for pre-hospital anaesthesia
- Describe the procedure for performing rapid sequence induction (RSI)
- Describe the procedure for failed intubation
- Define the training plan and final assessment for RSI

Background:

London HEMS carries out approximately one RSI a day. This equates to a service experience of approximately 4000 pre-hospital inductions. The algorithm has been developed to be straightforward and safe. For many years the algorithm consisted of RSI and surgical airway for failed intubation. This led to a surgical airway rate of around 2% - approximately half of which followed failed intubation and half performed as primary procedures (where intubation was not attempted). This compares well with emergency room surgical airway rates for severely injured patients. We have added alternatives in the latest algorithm following developments in airway management. We still expect the vast majority of our patients with airway compromise to either be intubated or get a surgical airway. We have no recorded cases of patients dying as a result of failed airway management after induction of anaesthesia. We mainly see two types of patients who require drug assisted intubation – those who can have a controlled procedure with a few minutes of preparation and a small group who require immediate intervention with little or no time for preparation. Training should prepare the pre-hospital Doctor for either situation.

Basic information on the drugs that we use can be found in the resource file. Etomidate is used as an induction agent, Suxamethonium and Pancuronium as muscle relaxants and Midazolam and Morphine for sedation, maintenance and analgesia. Ketamine with Midazolam is used for procedural sedation and analgesia. These particular drugs are used because of their relative haemodynamic stability and their relatively wide therapeutic margin – a 10 or 20% overdose is unlikely to cause significant problems (which is relevant in a working environment where patient weight is usually estimated). Pancuronium is used for it's sympathomimetic actions and relatively long duration of action (the vast majority of patients will only require one dose of Pancuronium to transport them to hospital).

Policy:

Indications for RSI

1. Actual or impending airway compromise
2. Ventilatory failure
3. Unconsciousness
4. Humanitarian indications
5. Injured patients who are unmanageable or severely agitated after head injury
6. Anticipated clinical course

The decision to anaesthetise patients should be made on the basis of an 'on-scene risk : benefit assessment' in every case i.e. in each specific situation do the potential benefits of RSI outweigh the potential risks?

Intubation Algorithm [appendix 1]

- Scene safety issues should be addressed as described in the scene safety SOP before RSI is considered.
- Access to the patient should be optimised prior to RSI. Where possible establish 360 degrees of access to the patient. Even for patients in near or absolute cardiac arrest this may be the first manoeuvre. This may involve moving the patient to another part of the scene or onto an ambulance trolley. Do not attempt intubation or RSI in confined or cramped conditions unless there is simply no alternative. It is preferable to perform RSI outside or on a trolley in an ambulance.
- Monitoring should be commenced with the Propaq (Encore). Remember the Norin monitoring device provides a reserve SpO2 and end tidal CO2 monitoring capability. Standards of monitoring satisfy the recommendations of the Association of Anaesthetists for in-hospital anaesthesia.
- Preparation for RSI: This should be automatic and absolutely standard. Everything should be aimed at optimising the first attempt at intubation. The flight paramedic should establish monitoring and rapidly provide a standard, laid out 'kit dump' **[appendix 2]** of equipment. Before commencing induction the doctor and flight paramedic should rapidly run through the 'challenge / response' RSI checklist. **[appendix 3]**.
- After administration of induction agent and Suxamethonium the trachea is intubated and tube position is checked by the following: direct vision (tube seen passing through cords, 'Easi-Cap' colourimetric CO2 detector / continuous sidestream CO_2 detection and auscultation in both axillae and over the stomach.
- Where an adequate view of the vocal cords cannot be obtained the '30 second' drills should be carried out. They are named to indicate that they should be easily completed long before a normal pre-oxygenated patient starts to desaturate.

Pre RSI sedation

- In agitated patients it may be necessary to use small amounts of sedation to facilitate pre-oxygenation. Small doses (1- 2mg of Midazolam) should be titrated to effect. In patients who are obviously hypovolaemic and hypotensive then even smaller doses should be used.
- In non head injured patients with severe limb trauma Ketamine (20 -30 mgs titrated to effect) can be used.

Pre-oxygenation

- In order to increase apnoeic time to desaturation all patients should be pre-oxygenated. The aim of pre-oxygenation is to maximise oxygen delivery to the circulation and to replace nitrogen in the lungs with oxygen.
  This is done by ensuring that the patient has a tight fitting face-mask with oxygen attached. A patent airway is essential to oxygen delivery and if necessary airway adjuncts should be used (nasopharyngeal, oropharyngeal, manual airway manoeuvres). Proper nasopharyngeal toilet should be performed with a soft suction catheter via the nasopharyngeal airways if required.

- Supplementary ventilation should be provided using a 2 person technique and BVM system if respiratory effort is inadequate or ineffective.

- In patients with severe facial injuries pre-oxygenation and induction of anaesthesia should be performed in the position where the patient is most comfortable and can maintain their own airway.

- Patients with a high BMI may benefit from pre-oxygenation in a slightly head-up position (with cervical spine protection maintained) or in the sitting position.

- If the patient desaturates to 92% during an intubation attempt, the assistant must inform the intubator and explicitly suggest that re-oxygenation should take place prior to a second attempt.

Failed intubation

- The I-Gel is the default device for ventilation following a failed intubation attempt. This device minimises gastric inflation and the risks of aspiration and is therefore preferable to BVM.
- If it is felt that no further changes can be made to improve the chances of successful intubation at a further attempt then a surgical airway should be considered. If anatomy / morphology of the neck suggest this will be difficult or the physician decides that the risks of surgical airway outweigh the possible benefits then the i-Gel should be left in place.
- In agitated patients with head injury and relatively high pre-induction GCS scores who were spontaneously breathing it may be appropriate to wake and transport to hospital spontaneously breathing. Cautious sedation may be required to maintain control of the situation. In our patient population even patients with GCS scores of 13 or 14 have a high rate of intracerebral pathology.

I-Gel Device

- Although we have added the I-Gel as an alternative airway device we expect it to be used rarely and expect the majority of failed RSIs in our system to receive a surgical airway.
- We have used it instead of a standard LMA because, even with adequate muscle relaxation, many of our patients require relatively high airway pressures. This device has been demonstrated to leak at higher airway pressures than the standard device.
- Insertion is straightforward. The device is inserted until the black line reaches the teeth. It is then tested and tied in place. It may 'mould' a little after insertion and improve the seal a few minutes after insertion. A size 4 I-Gel should fit patients from 40 – 90 kg +.
- It should be used in preference to BVM (Bag – Valve – Mask) ventilation to prevent gastric inflation and an increased risk of aspiration. It may rarely be inserted blindly into trapped patients in whom access is severely limited and augmentation of their ventilation is required.

Surgical Cricothyroidotomy

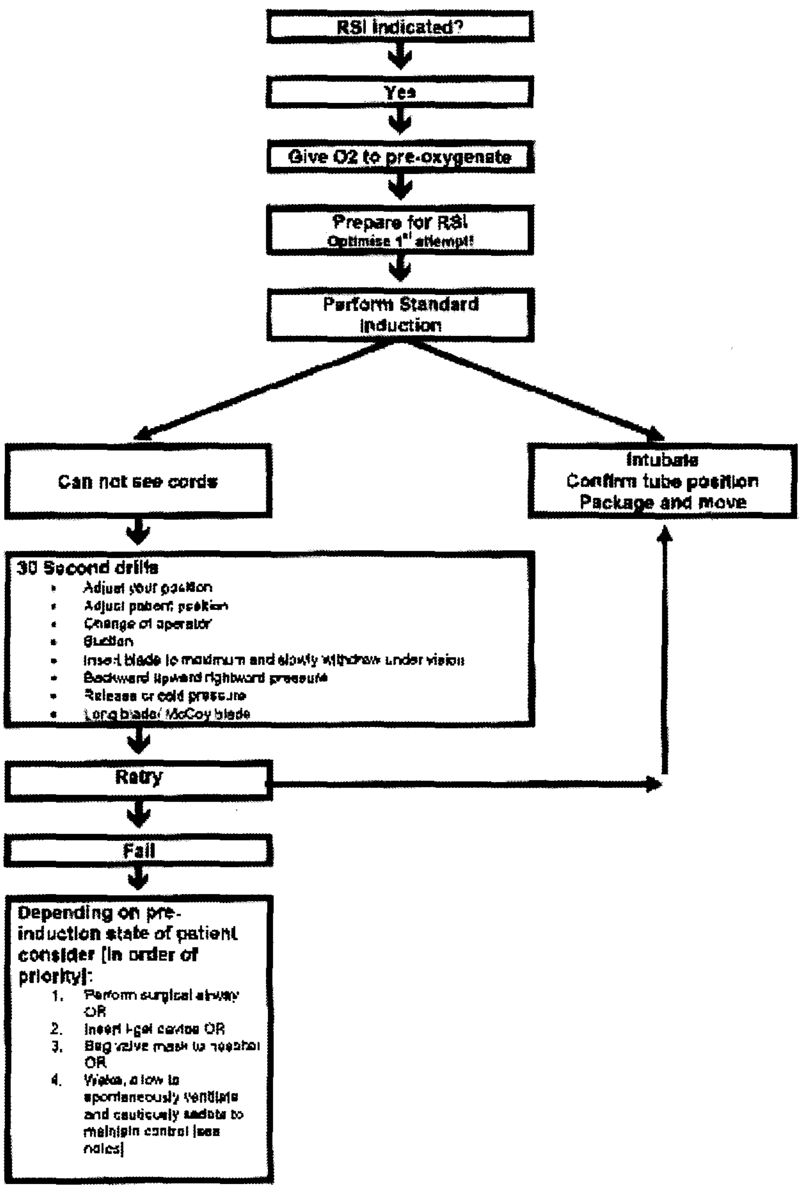
- The surgical airway equipment should be removed from its pouch when it is anticipated that an airway will be particularly difficult. For example:
    - Airway trauma
    - Difficult anatomy
    - Burns to face and neck precluding jaw movement
    - Possible airway burns

- The technique of surgical cricothyroidotomy we use is rapid, reliable and relatively easy. The Difficult Airway Society now recommends a very similar technique. It addresses two problems which we have commonly seen in the pre-hospital environment which make some of the 'standard' techniques less appropriate. These are bleeding from the incision and loss of the incision into the airway before or during tube insertion. A scalpel blade is carefully inserted horizontally into the cricoid membrane using a "stab / rocking" technique. Leaving the blade in position the tips of a tracheal dilator are pushed into the airway incision on either side of the blade and opened. The scalpel blade is removed and a **6.5mm** cuffed tracheal tube is inserted (over a lubricated intubating bougie if necessary) into the hole held open by the dilators. The dilators may need to be rotated 90 degrees to admit the tube. The cuff is inflated, tube position confirmed in the normal way and ventilation commenced. The tube is then fixed in position with a tie or elastoplast. The procedure should take around 30 seconds.

Paediatrics

- Pre-hospital anaesthesia of small children is only rarely required. For most children the risks outweigh the benefits. Where actual airway compromise cannot be overcome with simple airway manoeuvres the risk : benefit equation may change and drug assisted intubation may become appropriate.
- Equipment for paediatric intubation is kept in the 'paediatric intubation pack'. Drug dose side-memoires and Broselow tapes are available. If the age of the child is known initially, the drug doses should be calculated on the journey to scene.

Appendix 1 - HEMS Anaesthesia Algorithm



Appendix 2: The 'Kit-dump'

- Monitoring on – running on automatic setting at 3 minute intervals

- Spread out yellow disposable bag and lay out.
    - Laryngoscope [size 3 and 4 blade]
    - Bougie
    - ET tube [cuff tested]
    - Circuit: easicap, catheter mount, filter [side stream connected]. NB consider mainstream in older monitor.
    - 20ml syringe
    - Alternative smaller tube [cuff tested].
    - Alternative laryngoscope [alternative blade size].
    - 2 x nasopharyngeal airways
    - 1 x oropharangeal airway

- Ensure availability of:
    - Bag-valve-mask connected to O2 tubing.
    - Spare O2
    - Difficult airway kit [surgical cric./ surgical airway pouch]
    - McCoys
    - Spare drug roll

- Suction should be placed to the right hand side of the patient's head. The 'Yankaur' suction catheter must be tested.

Appendix 3: The talk through

The purpose of the talk through is to:

- Allow a defined period of preoxygenation
- Check that all the necessary equipment is present and working
- Ensure the position of the patient is ideal for intubating
- Reduce the chance of failed intubation

Every step in the procedure should be addressed in the order equipment will be used. This way no piece of equipment is missed out. While talking through ensure the patient has a tightly applied reservoir mask and that the reservoir is moving with respiration.

Step in Talk through	Common problem	Benefits
Check baseline observations and cycle time for propaq.	Propaq slipped into manual mode and displaying old readings	
Check oxygen reservoir mask is tightly applied	No seal on mask, bag not working as reservoir. Bag too cold and stiff to move in winter	Maximises pre-oxygenation
Check oxygen supply [where possible an E size cylinder]	Oxygen about to run out no reserves close at hand	Avoids hypoxia
Remove cervical collar		Jaw movement for laryngoscopy and cricoid / BURP
Check position of head and neck	Patient on scoop or floor with neck in extension, head in flexion, slight neck lat flexion	Maximises view.
Check drip is patent and easily flushes and not on side of BP cuff (or cuff down)	Drip not out in ay you may never have been in or may have tissued	Avoids partial or non delivery of drugs, minimises chances of failed intubation
Check drugs and doses to be given. Check operator familiar with the doses to be given	Excess given though miscommunication [see sedation and analgesia SOP]	Avoids hypotension, ICP spikes or failed intubation through inadequate paralysis.
Check operator can perform cricoid pressure, is on left of patient & understands BURP	Most ambulance staff do not know how to perform either correctly. Operator usually on patients right and makes view worse with BULP	Better view at laryngoscopy Minimises chances of aspiration
Check laryngoscope functions and working spare is present	Weak battery, damaged bulb	Equipment presence Equipment failure
Check suction is present and working	Not present at scene Weak battery with poor function Wrong suction device	Equipment presence Equipment failure
Check bougie	In summer the bougie can become very soft	Equipment presence Equipment failure
Check tube is correct size and balloon does not leak	Tubes cuff balloon has small leak	Avoids need for tube change
Check presence of catheter mount. Easicap, filter and capnography		Ensures tracheal position of tube
Check valves in self inflating bag that reservoir and oxygen supply are attached		Equipment presence Equipment failure
Check tie		Equipment presence

Appendix 3

Date	Time of Emergency Call	LAA Arrival Time	Scene Departure Time	Hospital Arrival Time

Age (years)	Gender (Male/Female)	Traumatic Incident Descriptor	Intubation performed (Yes/No)	RSI Delivered (Yes/No)

Appendix 4

Barts and The London NHS
NHS Trust

Helicopter Emergency Medical Service

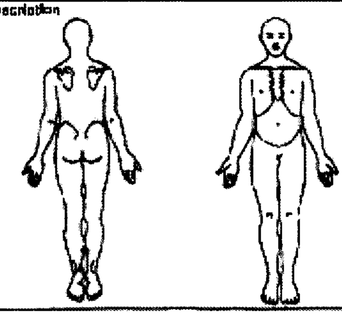
Dr	Para		Trainee / Observer	
Date	Amb Call Signs		CAD	
Location				
999 call	Activation	Arrive	Depart	Hosp
Immediate	Interrogation		Crew Request	
			M / F	Age /

Description of incident

On arrival A.............................. C.............................. B.............................. D..............................	Force Vector

Cord Function				Limb Movement			
Priapism	Yes / No / Not examined			Left arm	Yes / No / Not examined		
Deformity	Yes / No / Not examined			Left leg	Yes / No / Not examined		
Cardiovascular	Yes / No / Not examined			Right arm	Yes / No / Not examined		
Diaphragmatic Breathing	Yes / No / Not examined			Right Leg	Yes / No / Not examined		

Injury Description	Management



Drugs Est weight kg Anaesthetic Time	Etomidate Suxamethonium Pancuronium Morphine Midazolam	Ketamine Ondansetron Hypertonic saline % Other ____________

Total Prehospital Fluids:	LAS Fluid: ml	HEMS Fluid: ml	PRBC units

Intubation	ET tube size-	Blade	Bougie-	Cormack - Lehane grade-
Comments / reason for int'	ETT at teeth cms	Cuff cap	Sat'ing	

Code Red Yes / No	Tranexamic Acid 1g Yes / No	Spinal Immobilisation Yes / No	D/W PHC Cons Yes / No

	Time	Pulse	BP	RR	E / 4	V / 5	M / 6	GCS / 15	O_2 Sat (%)	Gluc	Pupil size R	Pupil size L	Reactivity R	Reactivity L
HEMS first obs														
HEMS final obs														

A+E / LAS HANDOVER		For further information HEMS - 0207 377 7000 Ext 3484
Laceration Yes / No	Other issues	Signed
Cord Normal / Abnormal / Ventilated		
Temperature		
Triage to		
Triage Rationale	MRN	

Appendix 5

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M131145

NAME:
(Principal Investigator) Dr Daniel Nevin

DEPARTMENT: Emergency Medicine
London's Air Ambulance, The Royal London Hospital,

PROJECT TITLE: Pre Hospital Paediatric Intubation

DATE CONSIDERED: 29/11/2013

DECISION: Approved unconditionally

CONDITIONS:

SUPERVISOR: Prof Efraim Kramer

APPROVED BY: Professor PE Cleaton-Jones, Chairperson, HREC (Medical)

DATE OF APPROVAL: 24/01/2014

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10C04, 10th floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**

Principal Investigator Signature M131145Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix 6

LONDON'S AIR AMBULANCE

London's Air Ambulance
The Helipad
Royal London Hospital
Whitechapel
London
E1 1BB

10 January 2012

Dear Dr Nevin

Permission for access to Database for purposes of research

This correspondence serves as written testimony that you are to be granted unrestricted access to the database belonging to the London Air Ambulance for the purposes of performing a retrospective audit on paediatric intubation. Access to the database will be expedited through the research assistant Mrs Elizabeth Foster. Please liaise with her directly in order to facilitate the project.

Yours sincerely

Anne Weaver

Dr Anne Weaver

Consultant in Emergency Medicine and Pre Hospital Care

Lead Clinician – London's Air Ambulance