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The haemodynamic response to pre-hospital RSI in injured patients☆

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ABSTRACT

Background: Laryngoscopy and tracheal intubation provoke a marked sympathetic response, potentially harmful in patients with cerebral or cardiovascular pathology or haemorrhage. Standard pre-hospital rapid sequence induction of anaesthesia (RSI) does not incorporate agents that attenuate this response. It is not known if a clinically significant response occurs following pre-hospital RSI or what proportion of injured patients requiring the intervention are potentially at risk in this setting.
Methods: We performed a retrospective analysis of 115 consecutive pre-hospital RSI's performed on trauma patients in a physician-led Helicopter Emergency Medical Service. Primary outcome was the acute haemodynamic response to the procedure. A clinically significant response was defined as a greater than 20% change from baseline recordings during laryngoscopy and intubation.
Results: Laryngoscopy and intubation provoked a hypertensive response in 79% of cases. Almost one-in-ten patients experienced a greater than 100% increase in mean arterial pressure (MAP) and/or systolic blood pressure (SBP). The mean (95% CI) increase in SBP was 41(31–51) mmHg and MAP was 30(23–37) mmHg. Conditions leaving the patient vulnerable to secondary injury from a hypertensive response were common.
Conclusions: Laryngoscopy and tracheal intubation, following a standard pre-hospital RSI, commonly induced a clinically significant hypertensive response in the trauma patients studied. We believe that, although this technique is effective in securing the pre-hospital trauma airway, it is poor at attenuating adverse physiological effects that may be detrimental in this patient group.

Introduction

Laryngoscopy and tracheal intubation are potent noxious stimuli. Without adequate depth of anaesthesia they provoke a marked neuroendocrine response characterised by acute hypertension and tachycardia.[1–4] It has been suggested that deeper levels of anaesthesia are required to blunt the response to laryngoscopy and intubation than the response to surgical incision. Although of less consequence in the healthy, this response is potentially harmful to patients with cerebral or cardiovascular pathology or haemorrhage.[5]

Prevention of this response in those at risk is an important anaesthetic objective.[6–8] Head injury and haemorrhage are major causes of trauma morbidity and mortality and patients with these injuries frequently require emergency intubation. Those with raised intracranial pressure, intracranial haemorrhage and major vascular injury are at particular risk of secondary injury following an adverse haemodynamic response.

Rapid sequence induction (RSI) is a well-established method of inducing anaesthesia to allow emergency intubation. A traditional technique, comprising pre-oxygenation, administration of a predetermined dose of a potent induction agent and suxamethonium followed by cricoid pressure is common practice in many physician led pre-hospital systems. This is also a recommended technique to secure the trauma airway in the current Advanced Trauma Life Support™ Guidelines and has often been adopted as the trauma standard.[9] The aim is to allow placement of a protective tracheal tube as quickly as possible as this sequence is thought to minimise aspiration risk. This technique has not, however, been shown to reliably prevent other risks, such as the pathophysiological consequences of airway stimulation.

The primary aim of this study was to describe the acute haemodynamic changes that occur in trauma patients following a

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standard RSI and tracheal intubation. Secondary aims were to describe the proportion of injured patients requiring pre-hospital RSI that may be vulnerable to secondary injury from an adverse haemodynamic response and to evaluate the influence of Ketamine and Etomidate on any response.

Methods

Study design

This was a retrospective observational study of trauma patients that underwent standard prehospital anaesthesia and tracheal intubation by Kent, Surrey and Sussex (KSS) Helicopter Emergency Medical Service (HEMS) between July 1st 2007 and October 1st 2008. The study was registered and approved by our Clinical Effectiveness Unit. Research ethics committee review was waived.

Setting and prehospital care system

The KSS Air Ambulance Trust operates two dedicated HEMS units providing a service to the 4.2 million people in the English counties of Kent, Surrey and Sussex. The medical crew consists of a senior doctor and paramedic and dispatch criteria target patients with major trauma or life threatening medical emergencies. Doctors have a minimum of five years postgraduate experience and appropriate post-graduate qualifications. An essential prerequisite is at least 6 months anaesthesia training and demonstrated RSI competence. Paramedics undergo Critical Care Paramedic training, including theoretical modules on RSI. Prior to independent pre-hospital practise, medical crew undergo an intense training period including structured medical education, training and operational supervision by pre-hospital care consultants leading to a formal "sign-off". A focus of this period is to ensure crew are competent at performing safe pre-hospital RSI. The service operates within a clinical governance structure that provides immediate access to advice from a consultant competent in pre-hospital anaesthesia, robust standard operating procedures, regular case review and ongoing training.

The decision to anaesthetise is based on an individual on-scene risk:benefit assessment. Indications include actual or impending airway compromise, ventilatory failure, unconsciousness, facilitation of management, anticipated clinical course and humanitarian reasons. Prior to induction the patient's position is optimised (ideally on an ambulance trolley with 360° access to head and neck), all necessary anaesthesia equipment is prepared in a standard 'kit-dump', non-invasive monitoring is commenced and the patient is pre-oxygenated for at least 3 min. Preparation is checked against a challenge-and-response checklist. To meet in-hospital monitoring standards, oxygen saturation, heart rate, electrocardiogram and sidestream capnography are continuously monitored using a HeartStart MRx portable monitor (Phillips Medical, Amsterdam, The Netherlands) Non-invasive blood pressure (NIBP) is measured every 3 min.

Anaesthetic drugs are pre-prepared in labelled syringes. Analgesic doses of Ketamine (0.5–1 mg/kg IV) are titrated, when indicated for painful injuries or procedures such as extrication or fracture reduction, prior to RSI. Induction is achieved with Etomidate (0–0.3 mg/kg IV) followed by paralysis with suxamethonium (1.5 mg/kg IV). The proportion of the induction dose administered (i.e. full, half or none) is determined by the patient's clinical condition. After induction the trachea is routinely intubated with a bougie and a tracheal tube railroaded into position. Correct placement is confirmed clinically and with a colorimetric CO_2 detector (Portex CO_2 clip) followed by continuous capnography. If required, 250 ml IV boluses of normal saline are administered to maintain a systolic blood pressure of 80 mmHg (or 100 mmHg in head injured patients).

Patient selection

All patients who underwent pre-hospital RSI during the study period were included. Patients in cardiac arrest and intubations performed for medical indications were excluded. We also excluded all cases with no monitor printout record of haemodynamic data.

Data collection

Data is prospectively collected on all patients treated by KSS HEMS. This involves completion of a written patient report form and electronic database (Easytask, Aerotech, UK), and a printout of the monitor recordings. The printout is at 3-min intervals, and usually annotated with explanations for any aberrant values and the timing of key interventions, such as RSI.

From these sources, data on patient demographics, mechanism of injury, injury pattern, Glasgow coma scale (GCS), RSI indication, RSI characteristics, dose of analgesic and anaesthetic agents and volume of IV fluid administered, were abstracted. Heart rate (HR), systolic blood pressure (SBP) and mean arterial pressure (MAP) were obtained at two distinct time points from the monitor printout. It is generally accepted that the haemodynamic response to laryngoscopy and intubation occurs within seconds of the stimulus and lasts up to 5 min after stimulation has ceased.[1,10] Baseline haemodynamic data were obtained prior to any intervention. Procedural haemodynamic data were obtained during a 5-min window beginning at the documented induction time. Where this was not available, a 5-min window beginning 1 min before successful intubation, indicated by commencement of capnography, was used. Cases where measurements at these two time points could not be recorded were excluded from further analysis of that measurement.

Definitions

Analgesic pre-medication was defined as any systemic analgesia administered prior to RSI. RSI was defined by the administration of suxamethonium. Full-dose Etomidate was defined as >0.2 mg/kg. The accepted definition of a haemodynamic response is an acute increase in measured haemodynamic indices during the period of laryngoscopy and intubation. The generally accepted anaesthetic objective is to maintain a stable blood pressure within 10–20% of baseline levels.[11] Patients with changes outside this are at increased risk of complications,[12,13] and acute elevations in blood pressure (>20%) are typically considered hypertensive emergencies.[11] We defined a hypertensive response as a greater than 20% increase in SBP/MAP above baseline and a hypotensive response as a greater than 20% reduction in SBP/MAP below baseline or a reduction in SBP to less than 90 mmHg. Similarly, a tachycardic response was defined as a greater than 20% increase in HR above baseline, and a bradycardic response was a drop in HR to less than 60 bpm. These definitions are consistent with other studies investigating the response.[14–16] Clinical indicators suggestive of significant haemorrhage were defined as baseline SBP <90 mmHg or heart rate >110 bpm, or both.

Statistical analysis

Statistical analyses were performed using SPSS version 15.0 (SPSS, Chicago, IL, USA). Categorical data are expressed as frequency (n), proportion (%) and analysed with χ^2 or Fisher's exact test as appropriate. Non-parametric data are expressed as

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median, interquartile range (IQR) and analysed with Mann–Whitney *U* test. Parametric data are expressed as mean ± standard deviation. Paired data was analysed using a paired *t*-test. A *p*-value < 0.05 was chosen to represent statistical significance.

Results

During the 14-month study period, KSS HEMS treated a total of 921 patients. Pre-hospital RSI was performed in 147 (16%) patients. Sixteen patients met the clinical exclusion criteria and a further 16 patients were excluded as there was no monitor printout. This left 115 trauma RSI's available for analysis. The median age was 39 years and the male-to-female ratio was 2.8:1. Prehospital RSI characteristics are shown in Table 1. Tracheal intubation was successful within 3 attempts in 100% of cases: 109 (95%) on first attempt, 5 (4%) on second attempt and 1 case required 3 attempts.

Measurement of the haemodynamic response

Baseline haemodynamic data was recorded, on average, 12 min before intubation. Of the 115 cases, 110 had a complete set of HR data and 89 had a complete set of NIBP data.

Cases with incomplete datasets were more likely to have received reduced-dose Etomidate or suxamethonium-only RSI (58% vs. 27%, $p = 0.01$) and increased fluid volumes (600 ml [IQR: 250–2125 ml] vs. 250 ml [100–725 ml]; $p = 0.005$) when compared to those with complete datasets.

Haemodynamic response

Laryngoscopy and tracheal intubation increased all mean haemodynamic variables; this difference was clinically and statistically significant (Table 2). A hypertensive response occurred in 79% (70/89) of patients. MAP exceeded the upper limit of estimated intact cerebral autoregulation (150 mmHg) in 18% (16/89) of cases and 9% (8/89) of patients had a greater than 100% increase in MAP and/or SBP. A single hypotensive response occurred. A tachycardic response occurred in 58% (64/110) of patients and bradycardia was induced in one.

Table 1
Characteristics of pre-hospital RSI in trauma patients.

Demographics	
Number of patients	115
Median age (range)	39 (2 – 99) years
Male	85 (74%)
Indication for RSI	
Unconsciousness	60 (52.2%)
Ventilatory failure	18 (15.7%)
Anticipated clinical course	16 (13.9%)
Airway compromise	15 (13%)
Humanitarian reason	3 (2.6%)
Facilitate injury management	3 (2.6%)
Analgesia prior to induction	
None	74 (64.3%)
Ketamine	41 (35.7%)
Morphine[a]	1 (<1%)
Etomidate dose	
Full dose	76 (66.1%)
Reduced dose	27 (23.5%)
None	12 (10.4%)
Induction muscle relaxant	
Suxamethonium	115 (100%)
Cormack and Lehane View[b]	
Grade 1	59 (52.2%)
Grade 2	42 (37.2%)
Grade 3	8 (7.1%)
Grade 4	4 (3.5%)
Bougie used	113 (98.3%)
Median fluid volume (IQR)	300 ml (200–850 ml)

Data are number (% of group total), unless otherwise indicated.
[a] This patient was also administered Ketamine analgesia.
[b] Only 113 patients with complete data.

Table 2
The haemodynamic response to laryngoscopy and tracheal intubation following a standard pre-hospital RSI. Data are presented as mean (SD) or (95% CI).

	Standard pre-hospital RSI		*p*-Value	Mean change
	Before	During		
MAP (mmHg)[a]	92 (20)	122 (29)	<0.001	30 (23–37)
SBP (mmHg)[a]	120 (27)	161 (39)	<0.001	41 (31–51)
HR (beats/min)[b]	95 (27)	116 (23)	<0.001	21 (14–28)

MAP, mean arterial pressure; SBP, systolic blood pressure; and HR: heart rate.
[a] Analysis based on 89 patients.
[b] Analysis based on 110 patients.

Injury characteristics

The majority (92%) of cases resulted from blunt trauma (Fig. 1). Head injury was common (Fig. 2) with 33 patients sustaining an isolated head injury and a further 64 patients sustained a head injury in addition to other injuries. Clinical indicators suggestive of significant haemorrhage were present in 38 patients.

Influence of administered drugs

The administration of Ketamine prior to RSI had minimal affects on the magnitude of the haemodynamic response to laryngoscopy and tracheal intubation (Fig. 3). The incidence of a hypertensive response was also similar between those that received Ketamine and those that received no analgesia prior to induction (81% vs. 77%; $p = 0.65$). The median dose of Ketamine administered was 100 mg (IQR: 53–150 mg). The two groups (Ketamine vs. No Ketamine) had similar baseline characteristics with the exception of GCS ≤ 8 (23% vs. 46%; $p = 0.01$).

The dose of Etomidate administered did not have a clinically or statistically significant influence on the magnitude of the haemodynamic response to laryngoscopy and intubation (Fig. 4). The incidence of a hypertensive response was also similar between those that received full-dose Etomidate RSI's and those that received reduced-dose or suxamethonium-only RSI's (80% vs. 75%; $p = 0.61$). All patients were administered Suxamethonium, mean dose 130 (SD 39) mg.

Discussion

Laryngoscopy and tracheal intubation, following a standard pre-hospital RSI, commonly induced a hypertensive response in the trauma patients studied. In certain cases this was of

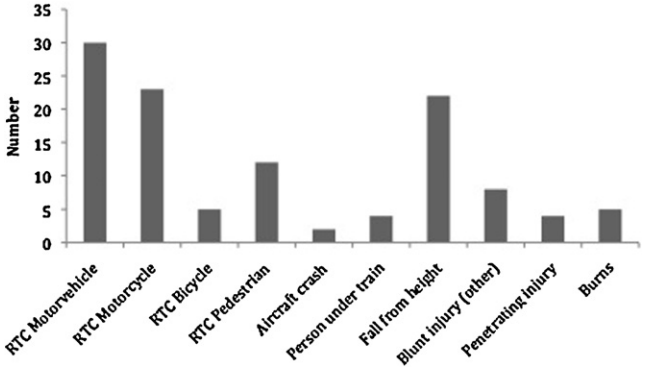

Fig. 1. Mechanism of Injury for patients undergoing pre-hospital RSI.

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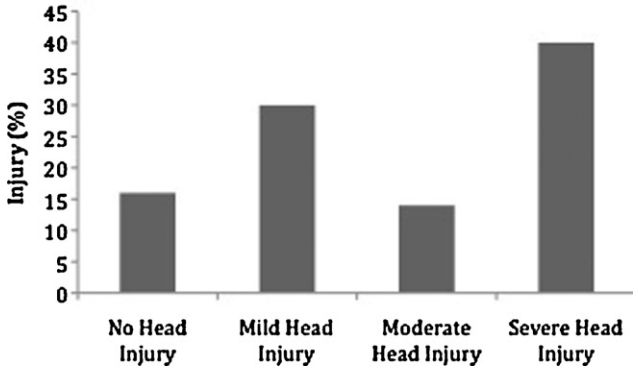

Fig. 2. Head injury severity in patients requiring pre-hospital RSI. Mild Head Injury (GCS 13–15); Moderate Head Injury (GCS 9–12); Severe Head Injury (GCS ≤8).

considerable magnitude, exceeding described physiological autoregulatory mechanisms. King and colleagues first described this response almost 60 years ago.[1] During light anaesthesia, they showed an average rise in SBP of 53 mmHg and increase in HR of 23 bpm. Although their study was performed under controlled conditions, using continuous invasive blood pressure measurement, their results are markedly similar to ours of 41 mmHg and 21 bpm, respectively. This is in contrast to a pre-hospital study that showed an average SBP increase of only 13 mmHg following a standard RSI technique.[17] This study may have underestimated the true magnitude of the response, as SBP measurements were infrequent. King's study noted that the response was unpredictable in magnitude and abolished by deeper levels of anaesthesia.

Anaesthesia is defined as a loss of response to noxious stimuli and usually consists of the triad: hypnosis, analgesia and neuromuscular blockade. Traditional RSI techniques however, only incorporate hypnosis and neuromuscular blockade. In trauma, Etomidate is a popular induction agent because it produces rapid hypnosis with minimal cardiovascular effects. Consequently, as a sole agent, it is unable to blunt the cardiovascular responses to noxious stimuli. This well documented pharmacodynamic profile is reflected in our findings that the dose of Etomidate administered did not influence the magnitude of the haemodynamic response.

In high-risk patient groups, a key objective of in-hospital anaesthetic induction is the avoidance of acute hypertension during airway manipulation.[7,8] Patients with severe injuries are an example of a population at risk for complications related to abrupt haemodynamic changes, and although more challenging, pre-hospital anaesthesia should meet the same recommended standards.[18]

In patients with traumatic brain injury, the prevention of secondary insults is of fundamental importance.[19] These patients frequently have impaired cerebral autoregulation. Surges in blood pressure can therefore produce sudden increases in cerebral blood flow (CBF) which in turn produce marked increases in intracranial pressure (ICP),[7,20,21] worsen cerebral oedema and promote rebleeding from injured intracranial vessels; increasing haemorrhage and haematoma size.[22] These are important secondary insults associated with worse neurological outcome.[23–25] Furthermore, a sudden increase in ICP could potentially precipitate brain herniation in patients with poor intracranial compliance.

Head injury was common in our cohort of pre-hospital RSI patients and unconsciousness was the primary indication for RSI in more than half of cases. Thirteen of the 16 cases where MAP exceeded the upper limit of estimated intact cerebral autoregulation occurred in patients being treated for a suspected head injury and the single bradycardic response was compensatory to severe hypertension induced in a patient with an isolated head injury. Thus, the possibility that the pre-hospital RSI technique may contribute to secondary brain injury cannot be overlooked.

Patients with vascular injury may also suffer serious sequelae as a result of an exaggerated haemodynamic response. Haemorrhage is a leading cause of preventable mortality[26] and episodes of acute hypertension and tachycardia may accelerate uncontrolled haemorrhage and precipitate rebleeding by mechanical disruption of

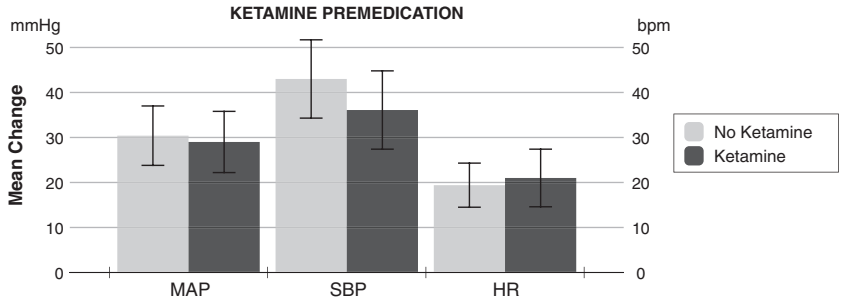

Fig. 3. The effect of Ketamine on the haemodynamic changes following tracheal intubation. Error bars represent 95 percent confidence intervals.

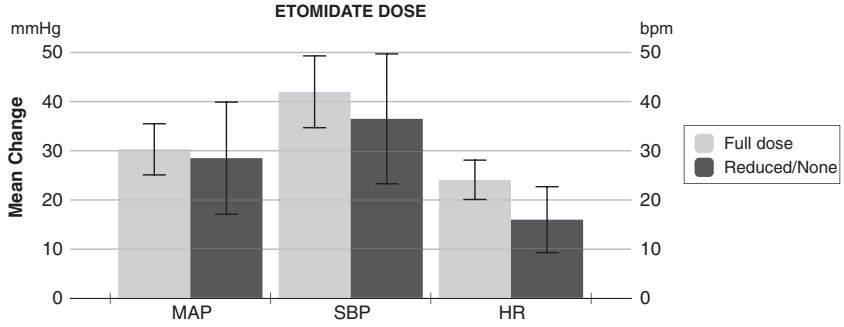

Fig. 4. The effect of Etomidate dose on the haemodynamic changes following tracheal intubation. Error bars represent 95 percent confidence intervals.

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initial thrombus.[27,28] One third of patients in our cohort had clinical signs suggestive of significant haemorrhage. In patients with blunt aortic injury, the second most common cause of death following blunt trauma, a sudden increase in aortic wall shear force may convert a partial disruption to a complete disruption with catastrophic consequences.[29] This mechanism may have been responsible for the only adverse hypotensive response in this study. Precipitous haemodynamic deterioration followed intubation in a patient who suffered a sudden deceleration injury. This patient had been normotensive for almost an hour prior to intubation and post-mortem revealed haemorrhage from a major vascular injury in the superior mediastinum.

Various agents can attenuate this response and provide potential for modification of the traditional RSI technique.[30] In line with the concept of a triad of anaesthesia, adding a synthetic opioid has been shown to be particularly effective.[14] In a national survey of UK in-hospital anaesthetic practise, the majority (75%) of respondents routinely modified RSI by adding an opioid.[31]

In pre-hospital anaesthetic practice there may be a reluctance to escalate the complexity of the procedure. Changing the technique risks decreasing the rate of one complication at the expense of increasing others. There is particular concern about failed intubation and hypotension in pre-hospital care. An alternative prehospital technique using propofol commonly resulted in acute hypotension.[32] This study confirms that the RSI technique described achieves excellent intubation success rates and that acute hypotension is rare, even in hypovolaemic patients. The addition of an opiate is likely to prevent an adverse hypertensive response but, although reversible, may cause prolonged apnoea and increased risk after failed intubation. After careful consideration, we developed a new pre-hospital anaesthesia standard operating procedure that includes the use of an opiate. The associated outcomes and complication rates will be carefully monitored and reported in due course.

There are several limitations to this study. Most notably, the retrospective study design, which may predisposes to an information bias. To minimise this, haemodynamic data was obtained from objective monitor printouts. Secondly, intermittent oscillometric NIBP measurement is not ideal for investigating acute haemodynamic changes as it may miss peaks and troughs in the response. Thirdly, missing data may also introduce a bias to data analysis. NIBP is at times unreliable in the pre-hospital environment, especially in haemodynamically compromised patients. This affected the completeness of blood pressure datasets in our study. As described, cases with incomplete datasets were more likely to have received reduced-dose Etomidate or suxamethonium-only RSI and increased fluid administration. In keeping with local standard operating procedures, these treatment options are indicated when haemodynamic compromise is suspected, suggesting that patients with incomplete datasets had worse haemodynamic compromise. This group seems particularly at risk, yet had to be excluded from analysis, thereby attenuating our findings.

Studies into the haemodynamic response to laryngoscopy and intubation have been criticised for not investigating patient groups at risk from the response and for making recommendations on modifying the response without showing improved outcome.[33] The aim of this study was to determine whether a clinically relevant response occurred in established high-risk patients. As all patients were subject to a similar stress there was no comparable group to produce meaningful comparative outcome data.

In conclusion, a clinically significant haemodynamic response to laryngoscopy and tracheal intubation was common following an unmodified, pre-hospital RSI. Furthermore, clinical suspicion of traumatic injuries aggravated by such a response was high in patients requiring pre-hospital intubation. The possibility that this pathophysiological complication could be contributing to iatrogenic morbidity and mortality in these patients raises concern. A means of safely reducing the number of people exposed to this risk warrants investigation.

Conflict of interest

No external funding received and no competing interests declared.

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