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Efficacy of pre-hospital interventions for the management of severe blunt head injury

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1. Introduction

Previous reviews of the efficacy of pre-hospital advanced life support (ALS) measures versus basic life support (BLS) measures for trauma patients have concluded that there is a paucity of quality research addressing this issue in the medical literature [1,2]. There has been on going controversy regarding the utility of pre-hospital ALS in blunt and particularly penetrating trauma victims. A meta-analysis of 174 articles on pre-hospital ALS versus BLS failed to demonstrate a benefit for on-site ALS and concluded with the recommendation that 'scoop and run' was the optimal strategy for trauma patients [3]. However, the sub-group of trauma patients with severe blunt head injury have largely escaped this debate. There has been a strong association demonstrated between presence of pre-hospital secondary insults, such as hypoxia and hypotension, and poor neurological outcome [4–7]. This has led to broad agreement that these patients benefit from ALS that will correct these secondary insults. However, recently produced evidence based guidelines concluded that there is insufficient data to determine a standard of care for any aspect of pre-hospital head injury management [8].

Although it has been demonstrated that secondary insults are associated with poor neurological outcome, this does not necessarily imply that aggressive attempts to correct these insults, when already present at the time emergency medical service (EMS) providers arrive at the scene, will result in improved outcomes. A significant degree of secondary injury may have already occurred and correction of these factors when already present may produce little additional benefit. Conversely, it is possible that without ALS, outcomes may be even poorer or that there is a benefit from prevention of subsequent hypoxia or hypotension where these insults were not present at the time of arrival of pre-hospital providers. Potential benefits in both these areas form the rationale for the use of ALS interventions.

The aim of this review is to examine the efficacy of pre-hospital interventions in both correcting and preventing the effects of secondary insults on the injured brain. Severe head injury is the major cause of trauma related death in western societies in persons less than 40 years of age and measures to reduce morbidity and mortality in this sub-population of trauma patients is therefore essential. As advanced pre-hospital care systems are expensive to implement it is also equally important that pre-hospital system developments designed to manage head injuries are based on sound evidence of benefit.

2. Airway management

As there is broad agreement that establishing and maintaining oxygenation is critical to outcome [9], and airway obstruction has been shown to be associated with a significant proportion of preventable pre-hospital trauma deaths [10], the debate has revolved around the method by which the airway is maintained. Particular attention has been focused on whether pre-hospital intubation is critical to outcome or whether other methods of maintaining oxygenation are adequate until arrival in hospital and definitive control of the airway can be achieved. A summary of the studies examining the relationship between pre-hospital intubation and outcome is presented in Table 1.

2.1. Time from injury to intubation

The only paper published in a peer-reviewed journal that has examined this issue [11] failed to find any correlation between time from injury to intubation and either mortality or morbidity.

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Table 1
Studies examining the efficacy of pre-hospital intubation for severe blunt head injury[a]

Reference and patient numbers	Study design	Inclusion criteria	Variables assessed	Results	Comment
[11], 166 patients	Retrospective, observational study	Blunt injury and GCS $\leq$ 8	Time from injury to intubation	No relationship demonstrated between time to intubation and either morbidity or mortality	Early intubation does not improve outcome
Without adjuvant neuromuscular blockade					
[12], 1092 patients	Retrospective, observational study	Blunt injury and GCS $\leq$ 8	Association of intubation and outcome, subgroups of severe head injury, isolated severe head injury, GCS = 3 and GCS > 3 reported	Significantly lower mortality associated with intubation in all subgroups and overall, no change in morbidity (as measured by discharge destination)	Pre-hospital intubation improves outcome
[14], 852 patients	Retrospective, observational study	GCS $\leq$ 8 and AIS $\geq$ 3 for head and neck	Association between intubation/attempted intubation and mortality	Significantly higher mortality in both intubated patients and those in whom intubation was unsuccessfully attempted	Pre-hospital intubation (and even attempted intubation) associated with higher mortality
[15], 830 patients, 61 with head injury	Randomised, controlled trial	All children requiring assisted ventilation in the pre-hospital setting	Morbidity and mortality, subgroups with multiple trauma and isolated severe head injury reported	No significant difference in morbidity or mortality overall or in the multiple trauma or isolated head injury subgroups	No benefit associated with pre-hospital intubation in children compared with BVM ventilation
With access to neuromuscular blockade, anaesthetic or sedative agents					
[18], 147 patients	Prospective, observational study	GCS $\leq$ 7	Association of intubation and mortality	Higher survival rate (67%) associated with intubation in GCS 3–5 but not GCS 6–7 (51%)	Intubation benefit only in patients with GCS 3–5.
[17], 179 patients	Prospective, observational study	Suspicion of head injury by treating doctor	Association between combination of correct endotracheal tube placement and ventilation with mortality	In isolated head injury, significantly lower mortality was associated with correct intubation and ventilation, no benefit seen in head injury patients with severe injuries to other body regions	Intubation and ventilation decrease mortality in isolated head injury but no benefit if the patients also have severe injuries to other body regions
[12], 502 patients	Retrospective, observational study	Blunt injury and GCS $\leq$ 8	Association of intubation and outcome, subgroups of severe head injury, isolated severe head injury, GCS = 3 and GCS > 3 reported	Significantly higher mortality associated with intubation in group of all patients with GCS $\leq$ 8, non-significant increase in mortality associated with intubation in all subgroups, Morbidity not reported	No benefit associated with NMB assisted intubation (possible increase in mortality)
[24], 1223 patients	Retrospective, observational study	ISS > 20	Association between intubation and multiple organ failure	Decreased multiple organ failure rate seen only in patients with ISS < 39 and severe thoracic or abdominal injury	No reduction in multiple organ failure associated with intubation for head injury

Table 1 (*continued*)

Reference and patient numbers	Study design	Inclusion criteria	Variables assessed	Results	Comment
[16], 314 patients, 75 patients with isolated severe head injury	Retrospective, observational study	Adult trauma patients requiring NMB assisted intubation, isolated severe head injury subgroup reported	Comparison of length of ICU and hospital stay, mortality and discharge disposition in patients intubated pre-hospital versus the emergency department	No difference in discharge disposition, death rate, hospital or ICU stay	NMB assisted intubation can wait till arrival in the emergency department
[19], 59 children	Retrospective, observational study	AIS for head and neck ≥ 4	Relationship between intubation and mortality in children intubated at the scene, regional hospital or trauma centre	Intubation in the trauma centre rather than other site associated with significantly lower mortality. Trend to lower mortality in the group intubated at the scene rather than regional hospital	Significant differences in injury severity between the groups make attributing observed differences to intubation alone impossible.
[20], 578 children	Retrospective, observational study	AIS for head and neck ≥ 4	Relationship between pre-hospital intubation and morbidity and mortality	No difference in mortality or functional outcome	No benefit associated with pre-hospital intubation in children
[21], 296 patients	Retrospective, observational study	Blunt injury and GCS ≤ 8 from motor vehicle trauma	Relationship between pre-hospital intubation and morbidity and mortality	Univariate analysis: intubated patients were 1.85 times more likely to have a poorer outcome, multivariate analysis: no association between intubation and outcome demonstrated	No independent benefit associated with pre-hospital intubation

[a] GCS, Glasgow coma scale; AIS, abbreviated injury score; ISS, injury severity score; ICU, intensive care unit; NMB, neuromuscular blockade.

2.2. *Intubation without adjuvant neuromuscular blockade, sedation or anaesthesia*

Studies examining the efficacy of intubation without neuromuscular blockade (NMB) are conflicting. Two studies are retrospective analyses of trauma registry data (Winchell et al. [12] and Murray et al. [14]) and the third is a randomised, controlled trial (RCT) of paediatric patients that required pre-hospital airway management, which reported outcomes in the subgroup of children with severe head injury (Gaushe et al., [15]). Reported outcomes in the retrospective studies contradict each other, with Winchell finding a significant mortality reduction associated with intubation. Murray however found a significantly increased mortality rate associated with intubation. Unsuccessful attempts at intubation were also associated with increased mortality, although not as strongly as successful intubation.

In Winchell's study [12], the intubated and non-intubated groups are not equivalent. One group could be intubated without adjuvant NMB whilst the other could not. Ability to intubate under these circumstances implies a lower level of intact reflexes and more severe injury, even where the GCS scores are the same. The observed mortality difference may be due to the fact that the groups were not neurologically equivalent. In this context, lower mortality in patients intubated without adjuvant neuromuscular blockade is an unexpected finding [13].

In Murray's study [14], intubation was attempted (successfully or otherwise) in only 16% of the patient sample; in those who were apnoeic or had inadequate appearing respiratory effort. An alternative explanation for the higher mortality observed in intubated patients is that these physical signs identify a subgroup of patients who have a higher likelihood of death. This would account for the apparent increase in risk of death associated with unsuccessful attempts at intubation as well as successful intubation. A significantly increased risk of death was also identified in intubated patients relative to unsuccessfully intubated patients which may again indicate that successful intubation without adjuvant neuromuscular blockade identifies a group of patients with more severe injury.

Gaushe's study [15] assessed the efficacy of bag–valve–mask (BVM) ventilation and rapid transport compared with BVM and intubation where possible without NMB.

The study was conducted in an urban area with short transport times (median 6 min) in children who required airway management for any reason. Outcomes for subgroups of children with multiple trauma and isolated head injury were also reported. There was no significant difference in pulse oximetry values on arrival in the emergency department (ED) between the patients managed with BVM (median 98% (IQR, 93–100%)) and those intubated (median 95% (IQR, 89–100%)). The study found no significant difference in survival overall, or in the subgroups of patients with multiple trauma (BVM only, 19%; BVM and intubation when possible, 24%) or isolated head injuries (BVM only, 32%; BVM and intubation when possible, 25%). Similarly, there was no significant difference in neurological outcome in survivors.

2.3. Intubation with access to adjuvant neuromuscular blockade

Winchell et al. [12] also examined 502 patients transported by an aeromedical team who attempted intubation in all unconscious trauma patients facilitated by NMB. In all patients with GCS < 9 (including those without severe head injury) the intubation rate was 86%. Mortality was significantly higher in the intubated group (35% versus 21%). In the sub-groups with severe head injury, and isolated severe head injury, there was also a trend to higher mortality in intubated patients. The authors attribute this higher mortality in the intubated patients to aeromedical crew judgement being used to avoid intubation in patients who, despite an initial GCS < 9, did not appear to have a severe head injury. However, patients with isolated severe head injury had a similar intubation rate (87%) to the population of all patients with a GCS < 9 (86%). The authors state that a decision not to intubate, rather than inability to intubate, was the reason for non-intubation in the aeromedical group; a clear selection process. However, as the reason for the selection decision is not clear, interpretation of the data is not possible.

Sloane et al. [16] found success rates for pre-hospital NMB assisted intubation to be similar to that in the ED (97.9% versus 98.5%, respectively) in adult trauma patients. In the subgroup of patients with isolated head injury there was no difference in ICU or total hospital stay, mortality or final disposition between the groups. This suggests that although NMB facilitated intubation can be accomplished with a high success rate in the pre-hospital environment, it makes no difference to outcome and it can be delayed until the patient arrives the ED.

Schüttler et al. [17] examined mortality in patients with isolated severe head injuries or with head injuries in combination with severe injuries to other body regions. Patients with isolated head injury who had adequate ventilatory therapy (defined as normoventilation or mild hyperventilation with correct placement of the endotracheal tube) had a mortality of 25% compared with 62% ($P < 0.05$) in those where there was a ventilation management deficiency. In patients with a severe head injury in combination with severe injury to chest or abdomen, there was no significant difference in mortality between the groups who received adequate versus inadequate ventilatory therapy.

Singbartl [18] studied 147 patients with GCS ≤ 7 injured in Germany of which physicians treated 136 and 11 were treated by BLS ambulance officers. Failure to intubate by the physicians was attributed to management error, rather than inability. Of those intubated with a GCS of 3–5, 32 of 48 (66.7%) survived. However, in the group with GCS 6–7 who were intubated, 16 of 31 (51.2%) survived ($P < 0.05$), suggesting that a benefit associated with intubation is seen only in patients with a GCS of 3–5.

Suominen [19] retrospectively studied intubation in 59 children with severe head injury defined by an abbreviated injury score (AIS) ≥ 4 for head and neck region. Twenty-four of the children were intubated at the scene (nine pharmacologically supported), 13 were intubated in the ED of a regional hospital and 22 in the ED of a Level 1 trauma centre. Patients intubated at the scene or the ED of the regional hospital had significantly higher mortality than those intubated in the ED of the Level 1 trauma centre. However, these patients also had significantly higher mean AIS and ISS, and lower GCS than those intubated in the ED of the trauma centre. There was a trend toward improved survival in the group intubated at the scene compared with intubation in the regional hospital ED ($P = 0.05$) but the mean GCS was significantly lower in the group intubated in the regional hospital ED (3.3 versus 4.3, $P < 0.05$). The inherent differences between the groups in severity of injury make attributing the mortality difference to pre-hospital intubation alone impossible.

Cooper et al. [20] examined the efficacy of intubation in paediatric patients with severe head injuries (AIS ≥ 4) in an attempt to confirm the findings of the RCT performed by Gaushe et al. In total 83% of the patients were intubated pre-hospital. This group was significantly older, more likely to receive intravenous fluids and have been transported by helicopter than those receiving BVM ventilation, but paediatric trauma scores and ISS were similar. Mortality was equal in both groups at 48% and functional outcomes were also similar. The proportion of patients who were intubated with adjuvant NMB is not stated. Use of NMB is common in helicopter programs in the US, which may account for the significantly greater proportion of patients transported by helicopter in the intubated group. The study suggests that there is no benefit associated with intubation, even with adjuvant NMB, in paediatric patients.

Garner et al. [21] retrospectively examined 250 patients managed by paramedics who could intubate without adjuvant NMB (35.6% intubated) and 46 by physicians who had access to NMB (100% intubated). All intubated patients were analysed together, without controlling for NMB. On univariate analysis, intubated patients were 1.85 times more likely to have a poorer outcome. However, when injury severity was controlled for on multivariate analysis, no significant association between intubation and outcome could be demonstrated.

2.4. Other potential benefits associated with pre-hospital intubation

Another theoretical benefit of intubation is better airway protection against aspiration. In Singbartl's study [18], 93 of 147 patients had been intubated. The rate of aspiration was lower in intubated patients (19% versus 46%, $P < 0.05$), as was the rate of consequent respiratory failure (35.5% versus 72%, $P < 0.05$).

Hypercapnia may exacerbate secondary injury by contributing to raised intracranial pressure. Another possible advantage of intubation over other methods of airway maintenance is better control of ventilation and correction of hypercapnia. Pfenninger and Lindner [22] prospectively collected arterial blood gas samples at the injury scene on 47 patients with head injuries (GCS 3 to GCS 15), before any pre-hospital interventions had occurred, including administration of oxygen by any means. $PaCO_2$ was found to have a very strong inverse correlation with level of consciousness. Patients with a GCS 3 had a $PaCO_2$ of around 60 mmHg compared with patients with GCS 15 who had a $PaCO_2$ of approximately 33 mmHg. Mean PaO_2 in all patients were supra-physiological by the time they arrived at hospital regardless of the type of airway management used. Patients who were intubated pre-hospital had significantly lower $PaCO_2$ on hospital arrival relative to $PaCO_2$ at the scene. This was not seen with patients who were left breathing spontaneously.

A retrospective, observational study by David et al. [23] examined the effect of pre-hospital mechanical ventilation on $PaCO_2$ in patients with head injuries and GCS ≤ 8. All patients had been intubated, sedated and connected to a mechanical ventilator prior to transport. Of 42 patients, 81% of the patients had either hypocapnia ($PaCO_2 < 30$ mmHg) or hypercapnia ($PaCO_2 > 38$ mmHg) on admission to the neurosurgical intensive care unit. Intubation and mechanical ventilation did not reliably result in normal CO_2 levels. Monitoring of end tidal CO_2 levels during transport was recommended.

Regel et al. [24] examined the association between pre-hospital intubation, volume resuscitation, tube thoracostomy and scene time, and subsequent multiple organ system failure (MOSF). Although intubation was associated with lower rates of MOSF in patients with severe thoracic and abdominal injuries, there was no reduction observed in patients with GCS < 9.

3. Correction of hypotension

There is substantial observational evidence that pre-hospital hypotension, even of short duration, is associated with poor outcome [5–7,25,26]. Hypotension is typically associated with severe injuries to other body regions [25] and, unlike hypoxia, is difficult to correct during pre-hospital management [6,26].

Three observational studies have reported outcomes following correction of hypotension in the field. In the first study [18], patients who were shocked on initial assessment ($n = 39$), were no more likely to survive with adequate versus inadequate pre-hospital volume resuscitation. However, in data from the Traumatic Coma Data Base with larger patient numbers, hypotension which was not corrected by the time of arrival in the ED of the receiving trauma centre was associated with a higher mortality (60.2% versus 50.0%) than patients with a episode of transient hypotension [7]. In another German study [17], patients with an initial systolic blood pressure $\leq$60 mmHg all died regardless of whether, in the opinion of the authors, adequate volume resuscitation to correct expected blood loss had been administered. SBP greater than 60 mmHg was then stratified by increments of 20 mmHg; 60–80 mmHg, 80–100 mmHg, etc. up to greater than 160 mmHg. There was a trend towards better survival in each band of SBP if the volume deficit was judged to have been adequately replaced. It reached statistical significance only in the 100–120 mmHg band which had the largest number of patients ($n = 58$ patients), where adequate volume resuscitation had a 12% mortality rate compared with 53% in those where it was considered insufficient ($P < 0.05$).

The fact that absence of even brief episodes of hypotension during the early management of head trauma is associated with better outcome [7,25] also suggests that there may be a benefit associated with fluid therapy aimed at prevention where hypotension has not already occurred. This is an inferred benefit and there is no direct data. Ethical considerations would prohibit controlled trials with a design that allocated patients to a treatment which allowed hypotension to develop.

4. Correction of anaemia

Pre-hospital anaemia has been demonstrated to be associated with poor outcome [25,26]. There is only one study that mentions pre-hospital transfusion [21], but there were insufficient patient numbers to assess any potential benefit.

5. Mannitol

There are no studies examining the effect of the pre-hospital use of mannitol on outcome in severe head injury.

6. Hypertonic saline ± Dextran

Hypertonic solutions have several theoretical benefits in pre-hospital resuscitation from combined haemorrhagic

Table 2
Studies comparing outcome of patients with severe burnt head injury treated by advanced intervention teams (AIT) or paramedic or other teams (POT)[a]

Reference	Patient numbers	Study design	Inclusion	Case assignment criteria	Team compositions	Management–AIT	Management–BLS/ALS team	Outcomes
[18]	AIT: $n = 136$, BLS: $n = 11$	Prospective observational cohort	GCS < 8	Not stated	AIT: "emergency physicians" or trainees BLS: BLS ambulance officers	68.4% intubated, neuromuscular blockade implied, dexamethasone, barbiturates, benzodiazepines, anticonvulsants, fluid resuscitation	BLS only	Survival (%) AIT 56.6, POT 18.2, $P < 0.05$
[29]	AIT: $n = 104$ ALS: $n = 128$	Prospective observational cohort	GCS < 9	POT patients from urban areas, AIT from rural areas on request from BLS unit	AIT: attending emergency physician and flight nurse, ALS: paramedics	100% intubated or cricothyroidotomy, hyperventilation, mannitol, dexamethasone, fluid resuscitation not stated	EOA only and hyperventilation, fluid resuscitation not stated	GOS (%); 1/2/3/4/5, AIT 31/13/16/9/31, POT 16/20/20/4/40, P (mortality) < 0.001, P (GOS 1–3) < 0.05
[30]	AIT: $n = 20$, BLS/ALS: $n = 24$	Retrospective observational cohort	Blunt injury, GCS < 9	Not stated	AIT: flight nurses with physicians either on board or providing on-line control. BLS/ALS: mainly paramedics but also patients transported by police, fire and private ambulance	80% intubated, controlled ventilation, 10% hypotensive on hospital arrival[b], not otherwise stated	10% intubated, 25% hypotensive on hospital arrival[b], not otherwise stated	GOS (%); 1–2/3–4/5, AIT 60/20/20, POT 38/8/54, P (mortality) = 0.02

Table 2 (*continued*)

Reference	Patient numbers	Study design	Inclusion	Case assignment criteria	Team compositions	Management–AIT	Management–BLS/ALS team	Outcomes
[31]	AIT: $n = 60$, BLS: $n = 40$, (Polish)	Retrospective observational cohort	Head/brain injury admitted to ICU	By ambulance dispatcher	AIT: physician and nurse team, BLS: BLS ambulance officers	Intubation (adjuvants not stated), intravenous fluids, osmotic agents	BLS only	Mortality by management transport only 51.6%, intravenous fluids 40%, intubation, intravenous fluids and osmotic agents 21.7%, $P < 0.05$, mortality by team AIT: 36.6% POT: 45%
[32]	AIT: $n = 196$, ALS: $n = 1090$	Retrospective observational cohort	Blunt injury, GCS < 9	AIT requested by POT team	AIT: flight nurses paired with another flight nurse, paramedic, emergency physician or emergency physician trainee, ALS: paramedics	100% intubated[c], neuromuscular blockade, controlled ventilation, sedation, lignocaine, mannitol, fluids to maintain mean arterial BP > 100 mmHg	52% intubated, (no adjuvants), otherwise airway via EOA, Combitube or BVM. Fluid resuscitation not stated	Mortality AIT 20%, POT 31%, $P < 0.05$, discharge to rehabilitation, AIT 25%, POT 15%, $P < 0.01$, discharge to extended care, AIT 5%, POT 11%, $P < 0.05$, discharge rate to home not significantly different
[21]	AIT: $n = 46$, ALS: $n = 250$	Retrospective observational cohort	Blunt injury, GCS < 9	POT from urban areas, AIT from rural areas, trapped patients or on request of POT unit	AIT: critical care physician and paramedic, ALS: paramedics	100% intubated, neuromuscular blockade, anaesthesia, sedation, intravenous fluids, packed red blood cells, mannitol	36% intubated (no adjuvants), intravenous fluids	GOS (%) 1/2/3/4/5, AIT: 39/22/20/0/20, POT: 18/30/19/2/31 $P < 0.05$, multivariate analysis: odds ratio for better outcome in AIT; 2.7 (95% CI: 1.48–4.95)

[a] GOS, Glasgow outcome score; 1, good recovery; 2, moderate disability; 3, severe disability; 4, vegetative; 5, dead.
[b] More aggressive volume resuscitation in the AIT group implied but not stated.
[c] Patients intubated without adjuvant neuromuscular blockade were excluded in this group but not in the POT transport group.
BLS, basic life support; ICU, intensive care unit; GCS, Glasgow coma score; EOA, oesophageal obturator airway.

Table 3
Relationship between scene and total pre-hospital time and outcome in patients treated by advanced intervention teams (AIT) or paramedic or other teams (POT)

Study	AIT pre-hospital times	POT pre-hospital times	Outcome
[29]	Mean 57 min (scene time: 17 min)	Mean 23 min (scene time: 10 min)	Significantly lower morbidity and mortality in the AIT group
[21]	Median 113 min	Median 45 min	Significantly lower morbidity and mortality in the AIT group
[32]	Mean 47 min	Mean 38 min	Significantly lower morbidity and mortality in the AIT group

shock and brain injury including correction of hypotension with small volumes of infused fluids, increased myocardial contractility, and reduced endothelial and cerebral oedema.

There are no published studies that directly examine the efficacy of pre-hospital administration of hypertonic saline (typically 7.5% with or without Dextran) specifically in the context of severe traumatic brain injury. There have been eight RCTs examining the efficacy of pre-hospital hypertonic saline in patients with traumatic hypotension. Post hoc analysis of some patient subgroups indicated a possible benefit, particularly in head injury [27]. Wade et al. in 1997 [28] published a synthesis of the sub-group of patients with severe head injury from 6 of the eight trials, which included access to the original case data. 223 patients with AIS ≥ 4 for head region were analysed. When trial and confounding variables were controlled for in a logistic regression model, hypertonic saline/Dextran was associated with an odds ratio of 2.12 ($P = 0.048$) for survival to discharge compared with standard of care (isotonic crystalloid solutions).

7. Total resuscitation "package"

Although the data on the efficacy of individual interventions is sparse and conflicting, there are a number of studies which have examined the efficacy of advanced intervention teams compared with either ALS or BLS capable teams [7,21,29–32]. These advanced intervention teams (AITs) either use non-physician personnel with extended protocols including NMB, sedatives, anaesthetic agents, surgical airways and osmotic agents or physician staffed teams that include these interventions in their scope of practice. A summary of the six studies is presented in Table 2. All the studies are observational with no randomisation. Case selection is either not stated or the group treated by the AIT were selected by dispatchers, or ALS/BLS units on the scene. All studies found significantly lower mortality in the group treated by the AIT. The four studies that examined morbidity also found an associated improvement in functional outcome.

In all of the studies, there are numerous differences in management between the treating teams. Attributing an outcome difference to one factor alone is therefore not possible. Only one of the studies includes a multivariate analysis [21] in which the type of team was the only treatment variable found to be significantly associated with outcome. A possible explanation of the observed outcome differences in these studies is that the combination of interventions provided by AIT have a cumulative benefit that is greater than the benefit accrued from interventions performed in isolation.

8. Effect of duration of total pre-hospital time

One of the ongoing controversies in pre-hospital trauma management relates to scene time. Long scene times, generally attributed to ALS interventions, are argued to cause delay in access to definitive care at the trauma centre and therefore increase mortality. As ALS interventions in pre-hospital head injury management have escaped this debate it is worth examining the literature to determine if there is any relationship between either scene time or total pre-hospital time and outcome in this patient group.

Four of the studies in Table 2 address this issue. Three of the studies [21,29,32] compare total pre-hospital times and outcomes by team, which is summarized in Table 3. Baxt et al. [29] also includes data on scene time. In the study by Dybkowska et al. [31], all times from dispatch to arrival at the scene were less than 10 min and this was not further considered. They then examined the relationship between time of arrival of the team on the scene to arrival of the patient at the hospital. Times are not compared by team but by interventions performed. Patients who had no interventions on scene had times of team arrival at scene to hospital arrival of less than 15 min. Mortality in this group was 51.6%. Those in whom scene arrival to hospital time was between 15 and 30 min all received intravenous fluids but were not intubated with a mortality of 40%. Those with scene to hospital times of 30–60 min received intubation ventilation, osmotic agents and correction of hypotension with intravenous fluids. Mortality in this group was 21.7%, significantly lower than the group who received transport only ($P < 0.05$).

In contrast to the literature on pre-hospital management of trauma patients in general, patients with severe blunt head injuries have better outcomes associated with longer total pre-hospital times when caused by higher intervention levels, in all four studies that have examined this issue.

9. Conclusion

Overall, there is a paucity of well designed studies examining efficacy of pre-hospital interventions for severe blunt TBI.

The data on the relationship between pre-hospital intubation and outcome in severe head injury is conflicting. The only RCT where intubation was performed without NMB, failed to demonstrate an outcome difference. There is no RCT examining the utility of intubation with adjuvant NMB. Until such a trial has been conducted, intubation cannot be considered a standard of care as evidence of benefit is lacking. Although many EMS systems are now introducing intubation protocols for non-physician personnel incorporating NMB, there is no compelling evidence that this is a superior technique of airway management because it results in improved outcomes or that the associated increase in risks and complications is justified. The only other evidence drawn from RCTs concerns hypertonic saline and this was derived from post hoc analysis of studies designed to test other hypotheses.

The only area in which all studies were positive were those investigating the efficacy of advanced intervention teams compared with either ALS or BLS ambulance officers. In these studies, longer pre-hospital times that were due to an increased intervention level, were consistently associated with better outcomes. However all these studies are observational, and the issue is deserving of further investigation in a RCT.

Despite the widespread belief that pre-hospital intubation and correction of hypotension improve outcome, there are no good quality studies that support this view. There is a critical need for RCTs that compare management strategies for the pre-hospital care of patients with severe head injuries.

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