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Review Article

Prehospital Airway Management in Severe Traumatic Brain Injury

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A B S T R A C T

Objective: Traumatic brain injury (TBI) is a leading cause of death and disability among trauma patients. The final outcome of TBI results from a complex interaction between primary and secondary mechanisms of injury that begin immediately after the traumatic event. The aim of this review was to evaluate the latest evidence regarding the impact of prehospital airway management and the outcome after traumatic brain injury.

Methods: PubMed, Embase, and Cochrane searches were conducted using the MeSH database. Airway management, traumatic brain injury, pneumonia, and the subheadings of these Medical Subject Headings were combined.

Results: The review is structured into 4 major topics: airway management devices, prehospital pharmacologic management, mortality and neurologic outcomes, and early respiratory infections. The available literature shows a shift toward a more comprehensive view of prehospital airway management, taking into account not only the location where airway management is attempted but also the drugs administered, the airway management devices used, and the skills of the main professional figures attending the scene.

Conclusions: Literature about this topic is still inconclusive; however, new evidence taking into consideration more complex aspects of airway management rather than orotracheal intubation per se shows improved outcomes with aggressive prehospital airway management.

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Traumatic brain injury (TBI) is a leading cause of death and disability in trauma patients, which result from a complex interaction between primary and secondary mechanisms of injury that begin immediately after the traumatic event. Prehospital management of severe TBI is fundamental in counteracting the main secondary mechanisms of injury, in particular hypoventilation, hypoxia, and low cerebral perfusion pressure, which should be prevented until definitive treatment can be provided.¹ For these reasons, prehospital airway management has a strong physiopathological rationale and forms a fundamental part of prehospital management of TBI in a number

of international guidelines.^{2–4} However, the effect on outcome variables of aggressive airway management has been the object of discussion in recent years following conflicting results published in the literature. Moreover, there is a high rate of disagreement in regional practice guidelines in the field of prehospital TBI management.⁵

Prehospital emergency services present a great heterogeneity worldwide in terms of the skills of health care providers, airway devices, drugs available on scene, times, and means of transport. This review highlights the most recent evidence regarding various key aspects of prehospital airway management and the outcomes of severe brain-injured trauma patients.

Methods

A PubMed search was conducted using the MeSH database. Airway management, traumatic brain injury, and pneumonia were

the 3 main subjects used to interrogate the database. Different subheadings of the 3 main Medical Subject Headings titles were combined in different couples using the Boolean operator “AND” in order to obtain 3 reference lists. Embase and the Cochrane Library were also searched using the same terms. The abstracts were reviewed by 3 independent researchers and those not relevant to the search were excluded; only English language articles were taken into consideration.

This review is articulated into 4 major topics: airway management devices, prehospital pharmacologic management, mortality and neurologic outcomes, and early respiratory infections. In the first 2 sections, we provided a description of the various devices and drugs that could have an application in the context of airway management, and then we summarized the most recent evidence about their risks and benefits in

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severe TBI population. The latter 2 sections are more specifically focused on the available evidence evaluating the impact of prehospital airway management on mortality and neurologic outcomes. Moreover, because this population is exposed to a high risk of aspiration and subsequent pneumonia contributing to secondary brain injury, we also included a short paragraph regarding the relationship between airway management and low respiratory tract infections.

Airway Management Devices

Airway management in trauma patients, especially in craniofacial trauma, is often challenging even for experts. In fact, the presence of airway reflexes and muscular tone, the necessity to maintain cervical spine stabilization, the frequent presence of blood, and secretions or gastric contents in upper airways significantly increase the difficulty to obtain a definitive airway.

The issue of intubation success rate is key in the field of prehospital trauma care, especially for the limited amount of equipment and personnel available outside the hospital. The international literature has tried to define competence and expertise in endotracheal intubation.^{6,7} A strong correlation with the number of airway procedures executed every year, the intubation success rate, and a low incidence of “rescue airway techniques”⁸ has been shown. However, especially for physician-staffed emergency medical systems (EMS), the number of procedures per year or a more comprehensive definition of “competent” and “expert” in airway management is hard to elucidate. Breckwoldt et al⁶ showed the applicability of the Dreyfus and Dreyfus system to airway management skills, but concrete implications of these findings on EMS staff training have not been drawn yet.

In recent years, alternative airway techniques, such as supraglottic airway devices (SADs), have been investigated in the field of prehospital medicine. There is a strong interest in these alternative devices because of the theoretical advantages they could offer in an out-of-hospital environment.

These devices are usually easier and faster to insert and manage.⁹ Moreover, second-generation supraglottic airway devices are safer for the risk of aspiration,¹⁰ and the most recent ones can also be used as a guide for blind intubation.

On the other hand, the role of SADs has traditionally been limited to rescue airway management in case of failed intubation with laryngoscopy or when tracheal intubation is not feasible because of the patient's constrained position (ie, during extrication of entrapped patients). Their use as primary airway devices has been limited because of

concerns related to suboptimal airway protection against gastric content aspiration¹¹ or rapidly evolving airway edema such as in burn patients. Also, after the use of an SAD as a primary airway, there is no consensus on the best way to approach definitive airway management.¹²

SADs have been more thoroughly investigated in the scenario of out-of-hospital cardiac arrest, and the most recent evidence suggests that, despite providing a good degree of protection against gastric aspiration and microaspiration, SADs remain inferior to tracheal intubation.¹³ Moreover, the use of an endotracheal tube, in contrast to an SAD, in the management of out-of-hospital cardiac arrest also seems to improve the probability of the return of spontaneous circulation and a better neurologic outcome.¹⁴

The most recent applications of SADs in the prehospital environment have investigated the possibility of blind intubation. Recent studies using mannequins, especially with unexperienced providers,^{9,15–17} show a higher percentage of correct orotracheal tube positioning using blind intubation through a previously positioned SAD, rather than with direct laryngoscopy, with a lower amount of time spent performing the maneuver. Despite the promising results of these studies on mannequins, no human studies on the trauma population are available regarding this particular possibility offered by SADs, which could prove interesting in the prehospital care setting.

In conclusion, airway management is a potentially lifesaving maneuver, but its failed attempt increases mortality.¹⁸ It seems reasonable to say that orotracheal intubation should not be attempted when providers do not have the sufficient competence and expertise required. However, competence and expertise are hard to formally define, and most guidelines have stopped indicating a minimum number of procedures per year to maintain skills.

More indications for the use of SADs could be found, rather than them being considered only a rescue device, despite the conflicting evidence regarding their performance in the out-of-hospital setting up until now. More research should be directed toward the use of SADs in the out-of-hospital scenario to include some specific indications, such as hemorrhaging patients, in which a contraction of prehospital times offered by a faster airway management could prove beneficial.

Prehospital Pharmacologic Management

Pharmacologic management of TBI in the prehospital setting is still a matter of debate. Many studies published in the literature do not report the type of drugs administered by the prehospital health care providers.

Moreover, prehospital teams in different countries may include physicians, paramedics, or nurses, who are often skilled in the use of a specific and limited selection of drugs; this further complicates the picture offered by the literature.¹⁹

The complexity of this scenario can be appreciated in [Table 1](#), which summarizes some of the relevant studies in this field. For more clarity, we have addressed this issue in 2 main chapters, analgesedation and neuromuscular blockade.

Analgesedation

Most intravenous anesthetic agents offer some grade of neuroprotection and facilitate muscle relaxation, therefore increasing the rate of successful intubation if muscle relaxation is not used. However, their hemodynamic effects in patients who are often hypovolemic could have detrimental effects on cerebral perfusion pressure. Also, in the case of failed intubation, the subsequent respiratory depression could worsen both hypoxia and hypercapnia.

Currently, the available evidence underlines the importance of drug-assisted rapid sequence induction (RSI). In fact, data from 2 large retrospective studies^{20,21} evaluating more than 23,000 patients and 1 randomized controlled trial (RCT)²² showed a significantly lower mortality and improved neurologic outcomes in the drug-assisted RSI cohort. The most used analgesedative agents described in the trauma literature are etomidate, midazolam, ketamine, and opiates.¹⁹

It is beyond the objectives of this review to discuss the different neuroprotective effects obtained with the various anesthetic agents in TBI patients. However, in the prehospital setting, hemodynamic stability has to be considered a primary objective when choosing the most appropriate anesthetic agent.

In this context, ketamine has gained increasing popularity. In fact, despite the increase in cerebral metabolism that ketamine induces, negative effects on intracranial pressure (ICP) or clinical outcome have not been shown in the literature.²³ Therefore, ketamine is now considered a safe drug in the prehospital setting, and its use is widely spread, in particular in hemodynamically unstable patients.²⁴

Etomidate is widely used in the prehospital setting, and it appears to grant intubating conditions and hemodynamic stability similar to midazolam.^{25,26} However, its use in critically ill patients, especially septic patients, has been challenged because of the possible induction of reversible adrenal insufficiency.²⁷ In this context, literature studies comparing etomidate and ketamine in prehospital helicopter emergency medical services²⁸ and trauma care setting²⁹ did not find

Table 1
Prehospital Intubation and Drugs

Year	Authors	Title	Type of Study	No. of Subjects	Main Findings	Limitations	Jadad Score
RSI vs. intubation without sedation							
2010	Bernard et al	Prehospital rapid sequence intubation improves functional outcome for patients with severe traumatic brain injury	RCT	312	No differences in mortality, better neurologic outcome in terms of eGOS		3
2012	Douglas Evans et al	Prehospital non-drug assisted intubation for adult trauma patients with a Glasgow Coma Score less than 9	Retrospective	2,229	Higher mortality in non-drug-assisted paramedic intubation		1
2017	Hoffmann et al	The impact of prehospital intubation with and without sedation on outcome in trauma patients with a GCS of 8 or less	Retrospective	21,242	Sedation before intubation significantly decreased mortality and improved early neurologic outcome		1
Analgo-sedation							
2004	Swanson et al	Comparison of etomidate and midazolam for prehospital rapid-sequence intubation.	Retrospective	209	No significant differences in terms of intubation success or hypotension	Trauma and non-trauma population	1
2006	Jacoby et al	Etomidate versus midazolam for out-of-hospital intubation: a prospective, randomized trial	RCT	110	No significant differences in terms of intubation success or hypotension	Trauma and non-trauma population	5
2012	Lin et al	Postintubation hemodynamic effects of intravenous lidocaine in severe traumatic brain injury	Retrospective	101	Lidocaine administration before RSI did not have hemodynamic effects and did not modify the dose of anesthetics used		1
2013	Price et al	Hemodynamic consequences of ketamine vs. etomidate for endotracheal intubation in the air medical setting	Retrospective	100	No differences in terms of hemodynamics and respiratory variables	General trauma population	1
2014	Rognas et al	Anaesthesiologist-provided prehospital airway management in patients with traumatic brain injury: an observational study	Prospective	54	Frequent post-RSI hypotension, especially in the propofol + opiate group		1
2017	Cameron et al	Comparison of etomidate and ketamine for induction during rapid sequence intubation of adult trauma patients	Retrospective	968	No differences in terms of mortality and hospital stay	General trauma population	1
2018	Takahashi et al	Association of fentanyl use in rapid sequence intubation with post-intubation hypotension	Prospective	1,263	Fentanyl group had a higher incidence of postintubation hypotension	Trauma and non-trauma population	1
NMBAs							
2011	Hiestand et al	Rocuronium versus succinylcholine in air medical rapid-sequence intubation	Retrospective	1,045	Succinylcholine was associated with a higher incidence of first-attempt intubation and reduced the number of attempts needed	General trauma population	1
2015	Lyon et al	Significant modification of traditional rapid sequence induction improves safety and effectiveness of pre-hospital trauma anaesthesia	Retrospective	261	Significantly better laryngoscopy views and first-attempt intubation in fentanyl + ketamine + rocuronium group vs etomidate + suxamethonium	General trauma population	1
2016	Patanwala et al	Succinylcholine is associated with increased mortality when used for rapid sequence intubation of severely brain injured patients in the emergency department	Retrospective	317	Higher mortality in the succinylcholine group		
2018	Bendinelli et al	A tale of two cities: prehospital intubation with or without paralyzing agents for traumatic brain injury.	Retrospective	283	Higher success rate when paralyzing agents were used. No improvement in either mortality rate or ICU length of stay.		1

eGOS = extended Glasgow Outcome Scale; ICU = intensive care unit; NMBAs = neuromuscular blocking agents; RCT = randomized controlled trial; RSI = rapid sequence intubation.

any differences in terms of mortality, hospital stay, postintubation hypotension, and hypoxemia between these 2 drugs. On the other hand, propofol, despite its widespread hospital use in severe TBI, was associated with severe hypotension when used in the prehospital trauma setting.³⁰

Lidocaine is often used as a premedication agent¹⁹ in order to blunt the ICP spikes during airway stimulation, and it has been shown to lower ICP.³¹ Moreover, a recent study from Lin et al³² showed in a retrospective series of TBI patients that using lidocaine as an adjunct to a standard RSI protocol did not have any detrimental hemodynamic effects on patients nor did it require modifications of the drug regimens necessary to achieve successful RSI. To date, we did not find studies regarding the use of intravenous lidocaine in the prehospital field. Fentanyl is 1 of the most widely used induction drugs for tracheal intubation. However, a recent study by Takahashi et al³³ investigated the use of fentanyl in emergency department (ED) airway maneuvers. These authors found a significant correlation with postintubation hypotension in patients who were premedicated with fentanyl. Moreover, a recent systematic review³⁴ confirmed that the use of fentanyl in RSI may increase the chance of postintubation hypotension, and it probably does not improve intubating conditions when added to a ketamine and neuromuscular blocking agent regimen. We did not find any study focusing on the use of fentanyl in the prehospital TBI population.

Finally, the ideal drug regimen for prehospital RSI is still a matter of debate. The focus should be on achieving good intubating conditions with a special regard to hemodynamic stability (both avoiding ICP spikes and arterial hypotension). Any provider performing airway maneuvers should be familiar with the drugs he or she is using.

A combination of ketamine and midazolam alone seems to be the best option for out-of-hospital maneuvers. In particular, expert opinion and an increasing amount of literature suggest this combination as the most indicated for hypotensive or hemorrhaging patients.

Neuromuscular Blockade

Neuromuscular blockade confers the advantage of increasing the probability of successful intubation and fosters the transition to mechanical ventilation. Succinylcholine (suxamethonium) is the most reported neuromuscular blocking agent followed by rocuronium.^{19,35,36} The addition of neuromuscular blockade to drug-assisted intubation provides superior intubating conditions and reduces the risk of traumatic intubation and aspiration.³⁷

A recent review from the Cochrane Library comparing rocuronium and succinylcholine for RSI concluded that succinylcholine creates superior intubating conditions compared with rocuronium; the suggested hypnotic agent to use was propofol.³⁸ However, these data are not specifically referred to the prehospital setting, and the detrimental hemodynamic effects of propofol in the hypovolemic trauma patient may question the applicability of these findings in the trauma field.

Two retrospective studies comparing rocuronium and succinylcholine in HEMS in the general trauma population have been published recently. Hiestand et al³⁹ found a higher frequency of first-attempt intubations and a lower number of attempts in the succinylcholine group. On the contrary, Lyon et al⁴⁰ found significantly improved laryngoscopy views and first-attempt intubation when RSI was obtained with fentanyl together with ketamine and rocuronium compared with patients receiving RSI with etomidate and suxamethonium.

The use of succinylcholine has raised some questions regarding its effects in increasing ICP. A recent retrospective study by Pantanwala et al⁴¹ found a correlation between the use of suxamethonium and an increase in mortality for patients with a high head Abbreviated Injury Scale who were intubated in the ED. However, other recent studies do not confirm these findings,⁴² and in general the evidence is not sufficient to recommend rocuronium or suxamethonium for RSI in TBI patients.⁴³ On the other hand, the long-lasting neuromuscular block obtained with rocuronium has raised some safety concerns in case of failed intubation in the out-of-hospital setting and may cause problems when attempting an early neurologic evaluation of patients. Despite the presence of sugammadex for the rapid reversal of neuromuscular block, its diffusion in the prehospital field is still limited.³⁵

Finally, the available evidence underlines how neuromuscular blockade increases the success rate of endotracheal intubation. There is insufficient evidence to strongly recommend the use of suxamethonium or rocuronium for this purpose. The availability of sugammadex in the prehospital environment could improve the safety of the use of rocuronium in the case of failed intubation.

Mortality and Neurologic Outcome

One of the main rationales for early airway management in TBI patients is the need to avoid a mismatch between oxygen demand and delivery to the brain tissue, thus reducing secondary brain damage. A variety of factors are involved in the development of secondary brain injury such as the development of intracranial hemorrhage, tissue hypoxia and acidosis, alterations in

ventilation, PaCO₂ and pH, metabolic alterations, and the formation of tissue and cellular edema affecting ICP. Early treatment and correction of the physiopathological derangements involved in TBI can have a positive effect on neurologic outcome.⁴⁴

The placement of an invasive airway in the field upon the first medical contact of a severe TBI patient has a strong theoretical rationale. However, this practice has been challenged by a number of studies in the past 2 decades.^{45–49} In a recent meta-analysis, Fevang et al⁴⁵ concluded that prehospital intubation, either with RSI or not, significantly increases the odds ratio for mortality in trauma patients with an on-scene Glasgow Coma Scale score < 9.

However, another recent meta-analysis from Bossers et al⁵⁰ evaluating the impact of operator's experience in airway management on mortality in severe TBI showed how low operator experience markedly increases mortality, whereas intubation attempted from highly skilled personnel (anesthesia and intensive care providers, specially trained paramedics and nurses) has no effect on mortality.

In recent years, 5 studies that were not taken into consideration in the previously mentioned reviews were published (Table 2). Three of them^{51–53} evaluated the impact of prehospital intubation in severe head injury and found no effects nor increased mortality in the prehospital invasive airway management group. Two other studies^{54,55} evaluated the impact of prehospital physician-based versus paramedic-only assistance in severe TBI; both studies found a significant decrease in mortality and a better neurologic outcome when physician assistance was added to standard paramedic care.

When investigating the outcomes of prehospital airway management, there is a lack of consensus on what should be considered a relevant outcome. Most studies found in the literature focus on the evaluation of the Glasgow Outcome Scale (GOS) at hospital discharge or at 1 year after the event. This is undoubtedly a strong patient-relevant outcome, but its correlation with prehospital airway management and in general to prehospital maneuvers is hard to highlight in a clinical study, in fact, the neurologic outcome of these patients is the result of the complex interaction of a number of medical, rehabilitative and social factors that act during time. Early hospital mortality (3 days) or Glasgow Coma Scale at 14 days, or Glasgow outcome at discharge, are possible intermediate outcomes that have been proposed, but few studies take them into account and their results are difficult to contrast.^{56–58} However, some recent literature suggests that prehospital airway management may have a role in improving neurologic outcome.^{21,49,51,54,59,60}

Table 2
Prehospital Airway Management in Severe Traumatic Brain Injury, Neurologic Outcome, and Mortality

Year	Authors	Title	Type of Study	No. of Subjects	Main Findings	Limitations	Jadad Score
2000	Murray et al	Prehospital intubation in patients with severe head injury	Retrospective	894	PHI significantly associated with mortality		1
2003	Bochicchio et al	Endotracheal intubation in the field does not improve outcome in trauma patients who present without an acutely lethal traumatic brain injury	Prospective	191	Higher mortality and nosocomial pneumonia in PHI group	Disomogeneity in cerebral lesions between the two groups	1
2005	Davis et al	The impact of prehospital endotracheal intubation on outcome in moderate to severe traumatic brain injury	Retrospective	13,625	Higher mortality in PHI group		1
2006	Klemen et al	Effect of prehospital advanced life support with rapid sequence intubation on outcome of severe traumatic brain injury	Prospective	124	Lower mortality in GCS 6-8 group, better functional outcome in ALS-assisted patients		1
2010	Vandromme et al	Intubation patterns and outcomes in patients with computer tomography-verified traumatic brain injury	Retrospective	334	PHI patients had higher overall injury severity, but this did not affect overall mortality		1
2010	Bernard et al	Prehospital rapid sequence intubation improves functional outcome for patients with severe traumatic brain injury	RCT	312	No differences in mortality, better neurologic outcome in terms of eGOS		3
2014	Karamanos et al	Is prehospital endotracheal intubation associated with improved outcomes in isolated severe head injury? A matched cohort analysis	Retrospective	220	Higher mortality and significantly lower pO ₂ in the PHI group. Significantly increased incidence of septic shock in the PHI group. PHI group had a longer hospital and ICU stay. As treated analysis 16% decrease in 30-d mortality in physician-assisted patients		1
2015	Garner et al	The Head Injury Retrieval Trial (HIRT): a single-centre randomised controlled trial of physician prehospital management of severe blunt head injury compared with management by paramedics only	RCT	375		Study discontinued because of poor recruitment and greater noncompliance	3
2017	Haltmeier et al	Prehospital intubation for isolated severe blunt traumatic brain injury: worse outcomes and higher mortality	Retrospective	16,278	Higher mortality, ICU, and hospital stay in the PHI group	Differences in ISS other than H-AIS, T-AIS, and A-AIS not described	1
2017	Pakkanen et al	Physician-staffed helicopter emergency medical service has a beneficial impact on the incidence of prehospital hypoxia and secured airways on patients with severe traumatic brain injury	Retrospective	266	Better neurologic outcome, lower incidence of hypoxia at hospital arrival, and more frequent successful airway management in physician-assisted events		1
2018	Rubenson Wahlin et al	Prehospital intubation and outcome in traumatic brain injury—assessing intervention efficacy in a modern trauma cohort	Retrospective	458	No differences in mortality or GOS		1

A-AIS = Abdomen-Abbreviated Injury Scale; ALS = advanced life support; eGOS = extended Glasgow Outcome Scale; GCS = Glasgow Coma Scale; GOS = Glasgow Outcome Scale; H-AIS = Head-Abbreviated Injury Scale; ICU = intensive care unit; ISS = Injury Severity Score; PHI = prehospital intubation; RCT = randomized controlled trial; T-AIS = Thorax-Abbreviated Injury Scale.

Hoffmann et al,²¹ in a very large cohort of patients, found a positive correlation between prehospital intubation and neurologic outcome defined as GOS at hospital discharge when patients were intubated and sedated in the field. Sedation and relaxation surely contribute to the success rate of airway maneuvers and probably also make mechanical ventilation more appropriate to reach therapeutic targets.

In a physician-staffed EMS with high rates of prehospital successful intubation, Pakkanen et al⁵⁹ showed that overall mortality was significantly improved compared with a paramedic-staffed EMS with low prehospital intubation rates. Long-term neurologic outcome was also improved but did not reach statistical significance.

Garner et al⁵⁴ also found an improvement in mortality for TBI patients being treated by advanced medical teams including physicians (and providing more advanced treatment measures such as prehospital airway management) but failed to show a statistically significant improvement in GOS at 6 months. A recent study by Wahlin et al⁵¹ analyzing a large retrospective cohort of patients in a modern European trauma system did not find a significant correlation between prehospital intubation and neurologic outcome. However, their results also show that a number of other factors correlated with a worse outcome in previous studies did not show such a correlation in their sample (eg, hypoxia). These authors speculated that this could mean that the correct patients were intubated in the prehospital setting, therefore blunting the negative effect on outcome of other knowingly detrimental factors. Analyzing the data originating from the PROTECT III trial, Denninghof et al⁶¹ showed improved outcomes with prehospital intubation. These authors underline how these results, which contrast from previous reports originating from North American trauma systems, may be related to a more controlled population, a better selection of patients, and the exclusion of confounding factors. Finally, Popal et al⁶² reviewed the effects of a physician-staffed EMS, showing no clear benefits of the deployment of physicians in the prehospital management of TBI. However, the subpopulation of the most severe TBI patients seemed to benefit from physician management in the prehospital setting, which includes a more aggressive management of the airway and correction of physiological derangements.

In conclusion, the available evidence regarding the influence of prehospital airway management on neurologic outcome after TBI shows contradictory results. The studies available have a high heterogeneity and tend to focus on outcomes hard to

contrast in a review. However, the literature suggests that the more severe TBI patients seem to draw a greater benefit from earlier and more aggressive airway treatment, in particular if severe TBI is not associated with other contemporary severe traumatic lesions or hemorrhagic shock.

Early Respiratory Infections

Severe TBI is associated with loss of airway reflexes and increases the risk of micro- and macroinhalation of gastric and pharyngeal contents with subsequent development of early-onset ventilator-associated pneumonia (VAP). Therefore, early airway management should rationally reduce this phenomenon and have a protective role.

The literature in this field is scarce, and most of the available studies take into consideration the general trauma population and do not differentiate early-onset VAP from late-onset VAP.^{14,63-66} In fact, although early-onset VAP occurrence could rationally be related to prehospital airway management, it is much harder to imagine a role of prehospital intubation in late-onset VAP.

We found 3 studies evaluating early-onset VAP in severe TBI populations,⁶⁷⁻⁶⁹ which showed an incidence ranging from 24.3% to 60.6% (Table 3). Both Esnault et al⁶⁸ and, more recently, Gamberini et al⁶⁹ specifically evaluated prehospital airway management as a potential risk factor for early-onset VAP, but no significant association has been found.

Discussion

The available evidence in the field of prehospital airway management in TBI gives contrasting indications to clinicians thus far. A large portion of the available literature is retrospective, and the quality of the reviewed articles (which we summarized by indicating the Jadad scale for each of the studies reported in the tables) is overall low. Moreover, the specific characteristics of the prehospital setting, where diagnostic tools are very limited and most of the medical decisions are based on clinical scores, make standardization and interpretation of results hard.^{18,45,47,48}

Sollid et al⁷⁰ published a consensus-based template for uniform reporting of data in prehospital advanced airway management, taking into consideration many crucial variables discussed earlier. However, most of the subsequently published studies did not adhere to this template, so data reporting still remains unfavorable to an effective comparison in between different studies. A very recent review of the previously mentioned template for uniform reporting of data in prehospital advanced airway management is now available.⁷¹

Table 3
Prehospital Airway Management in Severe Traumatic Brain Injury and Pulmonary Infections

Year	Authors	Title	Type of Study	No. of Subjects	Main Findings	Limitations	Jadad Score
2015	Jovanovic et al	Risk factors for ventilator-associated pneumonia in patients with severe traumatic brain injury in a Serbian trauma centre	Prospective	144	Incidence 24.3%; risk factors: thoracic injury, higher ISS, coma upon admission; survival 45.7% vs 69% in non-VAP group		1
2017	Esnault et al	Early-onset ventilator-associated pneumonia in patients with severe traumatic brain injury: incidence, risk factors, and consequences in cerebral oxygenation and outcome	Retrospective	175	Incidence 60.6%; risk factors: therapeutic hypothermia, thoracic AIS score ≥3, gastric aspiration; Negative impact on cerebral oxygenation and independently associated with unfavorable outcome at 1-year follow-up		1
2019	Gamberini et al	Early-onset ventilator-associated pneumonia in severe traumatic brain injury: is there a relationship with prehospital airway management?	Retrospective	223	Incidence 58.7%; no association between airway management devices, use of muscle relaxants, prehospital sedation, type of transport, and early-onset VAP		1

AIS = Abbreviated Injury Scale; ISS = Injury severity score; VAP = ventilator-associated pneumonia.

Recent literature about prehospital care in TBI is shifting the focus from prehospital intubation as a decontextualized variable to a more comprehensive view of prehospital airway management. This takes into consideration not only when the airway procedure is performed (prehospital vs. ED) but also who is the leading health care provider managing the scenario (physician, paramedic, and nurse) and how the airway instrumentation is performed (RSI vs. no drugs or alternative devices). When these aspects are taken into consideration,^{21,22,50,54,55,72} the effects on hard end points such as mortality and functional outcome appear to be favorable.

The role of SADs in prehospital trauma context and TBI used as a primary airway, a rescue device, or a conduit for blind intubation still needs to be clarified, and more data are needed.

Conclusion

Prehospital airway management in severe TBI is still a key point of research in the brain injury field. Currently, the literature about this topic is still inconclusive. However, in more recent studies, a shift toward a more comprehensive view of prehospital airway management is evident.

When airway management is considered as a comprehensive strategy involving 3 key elements (operator's experience, airway management devices, and pharmacology) rather than orotracheal intubation per se, the effects on hard end points are favorable. More research is still needed to elucidate some key points in this field, and a more uniform way of data reporting would greatly benefit future researchers. In order to improve uniformity and comparability of future research, the use of a common template for data collection, such as the one proposed by Sollid et al⁷⁰ and Sunde et al⁷¹ is strongly recommended.

Supplementary materials

Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1016/j.amj.2019.06.001>.

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