Prehospital Rapid-sequence Intubation—What Does the Evidence Show?

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This article is a summary of the proceedings from a panel presentation and discussion "Prehospital Rapid-sequence Intubation—What Does the Evidence Show?" presented at the National Association of EMS Physicians (NAEMSP) annual meeting, Tucson, Arizona, in January 2004. The presenters, Henry E. Wang, MD, MPH, Daniel P. Davis, MD, and Marvin A. Wayne, MD, are nationally recognized leaders in the research and practice of prehospital endotracheal intubation (ETI) and rapid-sequence intubation (RSI). In the opening section, "Prehospital RSI—Why Consider It At All?" Dr. Wang presented an in-depth review of the scientific evidence behind commonly cited reasons for prehospital RSI. Dr. Davis followed with "Pre-hospital RSI—Does It Make a Difference?" in which he discussed prior and current evidence linking this prehospital intervention to patient outcomes, including data from the recent San Diego RSI trial. Finally, in "Bellingham, Washington—A Prehospital RSI Success Story," Dr. Wayne presented an example of a highly successful prehospital RSI program and its secrets for success.

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Prehospital RSI—Why Consider It At All?

In this section, we describe the origins of prehospital RSI and review the evidence supporting commonly cited reasons for using prehospital RSI.

Origins of RSI

Rapid-sequence intubation (RSI) originated as the anesthesia technique "rapid-sequence induction." First described by Stept and Safar, rapid-sequence induction was prescribed as a sequence of 15 steps to rapidly induce anesthesia and prevent aspiration in patients with full stomachs.[1]

It is not clear when drugs were first used to facilitate emergency department (ED) ETI. However, a report by Taryle et al. in 1979 highlighted the pitfalls and complications of emergency ETI, including the fact that emergency ETI often takes place on combative, critically ill patients.[2] The authors laid the foundation for ED RSI by suggesting that emergency ETI could be assisted by "the more liberal use of procedures in the operating room, such as sedation and muscle relaxation." RSI became popularized in the ED in the 1980s and appears to have paralleled the development of emergency medicine as a specialty. Thompson et al. and Roberts et al. provided two of the earliest descriptions of ED RSI.[3,4]

Today, RSI is used as a technique for rapidly gaining control of the airway to facilitate rapid placement of an endotracheal tube and is considered a standard part of emergency medicine practice.[5] As described by Dronen, "In the critically ill patient who may be hypoxic, hemodynamically unstable, agitated, uncooperative, and at risk of further deterioration, it is frequently necessary to gain immediate control of the airway."[6] The secondary intention of RSI is to blunt the patient's physiologic response to laryngoscopy.[6] This is theoretically helpful in cases where the patient's physiologic state may not tolerate the stress of ETI. While there are many different methods for accomplishing RSI, all strategies universally include the combination of a sedative agent (usually an induction agent such as etomidate) with a neuromuscular-blocking (paralytic) agent (such as succinylcholine).

It is not clear when RSI was first used in the prehospital setting. Anecdotal reports of prehospital RSI date back to 1972 in Seattle, Washington (personal communication, Wayne M, Feb 1, 2000). Hedges et al. made the first formal report of prehospital RSI in 1998, describing 95 RSIs performed by paramedics in Thurston County, Washington.[7] Since then, at least 25 studies have described the use of prehospital RSI by either ground or air medical emergency medical services (EMS) units.[7–31] A survey conducted in 1997 indicated that at least 29 states permitted the use of neuromuscular-blocking agents by EMS units.[32] Current figures are probably much higher.

Are Sedatives Alone Adequate for Facilitating Intubation?

Sedatives have been widely used in both the prehospital and the ED settings to facilitate ETI.[33–36] Since sedatives theoretically do not completely ablate protective airway reflexes (as paralytics), some clinicians favor sedation-facilitated ETI (SFI) as a "safer" alternative to RSI for selected clinical scenarios.[37,38]

Current data suggest that SFI may not be adequately effective in the prehospital setting. For example, midazolam is widely used for SFI. Wang and colleagues previously reported a series of 72 midazolam-facilitated ETIs performed by paramedics in Delaware; the successful ETI rate was only 62.5%.[33] Preliminary data from New York in 2002 suggest that etomidate alone may be a potential alternative for facilitating ETI.[35] However, this small series found only small improvement over the use of diazepam. Bozeman and Young reported a series of 44 etomidate-only ETIs performed by air medical rescuers; whereas the success rate was 89%, significant ETI difficulties were associated with masseter spasm resulting from the drug.[36] The State of Delaware has an abundance of clinical experience with etomidate-only ETIs; for 2003, the state observed a success rate of 85.7% (108 of 125) (personal communication, Megargel R, Jan 2004).

These studies collectively comprise only a limited number of patients, but the same themes emerge—SFI results in ETI success rates that are borderline and that many would consider inadequate.

Do Most Prehospital Intubation Failures Occur on Inadequately Relaxed Patients?

Many clinicians believe that prehospital RSI would be used frequently because most prehospital ETI failures occur on inadequately relaxed, "awake" patients. However, current data suggest that this may not the case. First, prehospital ETI failures do not occur only on awake patients. For example, in a prior effort, the Prehospital Airway Collaborative Evaluation, Phase I (PACE I), Wang and colleagues collected multicenter data describing 742 prehospital ETIs.[39] They found that approximately 40% of prehospital ETI failures occurred on patients in cardiac arrest. Second, the demography of EMS airway management involves mostly cardiac arrest victims, patients who are not candidates for RSI. In prior data from PACE I and the State of Delaware, Wang et al. observed that approximately two-thirds of field ETIs occur on patients in cardiac arrests.[39,40] The ETI success rates for the cardiac arrest and non-arrest subsets were approximately 93% and 77%, respectively.

The projected need for prehospital RSI is actually quite small. In a *post hoc* analysis of the PACE I series, Wang and colleagues found that of the 741 total ETI patients, 35 received prehospital RSI and only 12 received ED RSI.[39] This observation suggests that only approximately 5% of prehospital ETIs potentially require RSI. This figure translates to very small RSI-per-paramedic numbers. Approximately 1,350 advanced life support (ALS) personnel were involved in the PACE I series; the 5% figure translates to roughly one RSI per 18 rescuers. As a second example, the City of Pittsburgh EMS, an extremely busy urban EMS system, has approximately 170 paramedics and performs approximately 350 ETIs per year (personal communication, Roth R, Feb 2004). The 5% figure translates to 18 RSIs per year, or only one RSI per paramedic per decade.

In contrast, the demography of ED airway management is quite different from that in the prehospital setting. The majority of ED ETIs occur on non-arrest/awake patients.[41,42] Therefore, widespread use of RSI in the ED is not simply a result of physician choice, but rather a reaction to the reality of the patient population handled in this setting.

Could the Factors that Result in Failed Prehospital ETI Be Corrected by RSI?

Many clinicians believe that the factors that cause prehospital ETI failure could be corrected or rectified by RSI. While there are data exploring the area of failed prehospital ETI, these data have important limitations. In a series of 236 ETIs performed by a ground ALS service, Doran et al. found that "technical problems," "mechanical problems," and "combative patients" increased "ETI difficulty."[43] Krisanda et al. associated altered level of consciousness, difficult anatomy, and obstruction with field ETI difficulty.[44] Karch et al. retrospectively examined 94 trauma patients undergoing attempted field ETI and found that "gagging," "combative patient," "blood/vomitus in airway," "facial trauma," and "trismus" were reported as reasons for unsuccessful ETI.[44]

Because multiple factors may concurrently impede ETI success, Wang et al. performed a *post hoc* analysis of data from PACE I.[45] They excluded patients who received RSI or SFI. The authors identified 61 clinical variables with plausible relationships to ETI failure. Using multivariate logistic regression with a stepwise covariate selection procedure, seven factors were identified that were independently associated with ETI failure: presence of clenched jaw/trismus, inability to pass the endotracheal tube through the vocal cords, inability to visualize the vocal cords, intact gag reflex, intravenous (IV) access established prior to ETI attempt, increased weight, and electrocardiographic (ECG) monitoring established prior to ETI attempt. Many of these factors (trismus, intact gag reflex, inability to pass the tube through the vocal cords) are markers of inadequate relaxation and plausible reasons for using RSI.

Wang et al. conducted a follow-up subset analysis to see whether practice patterns were actually consistent with these findings.[46] They identified the subset of non-arrest patients requiring ETI. Using a similar stepwise multivariate selection procedure, the authors identified the characteristics of the subset that received drugs to facilitate ETI. They found that trismus, the use of cervical spine precautions, and increased verbal Glasgow Coma Scale score were the most common unifying characteristics of patients receiving RSI or sedation-facilitated ETI.

It is important to note that the analyses described above represent exploratory efforts only. We endeavored to identify associations only, not to develop perfect prediction models; these models have not been externally validated. We also did not intend to use these analyses to evaluate the potential use of RSI in these patients. Therefore, while these analyses lay out original methods for approaching these scientific questions, future efforts must build upon the science used in these studies.

If RSI Saves Lives in the ED, Shouldn't RSI Save Lives in the Prehospital Setting?

Many EMS procedures are adopted because of supporting data from ED studies; the benefit of ED treatment is assumed to translate when applied to patients in the prehospital setting.[47] Many clinicians assume that because RSI is beneficial for ED patients, a similar benefit should be observed for prehospital patients. Ironically, the effectiveness of ED RSI has not been formally studied. Therefore, it is impossible to even speculate whether there is potential translation of effect to the prehospital setting.

The body of current data regarding ED RSI has focused on success rates, the hemodynamic effects of selected drug agents, and adverse events.[3,4,41,42,48–63] There are only limited data formally evaluating the mechanisms of ED RSI and their effects on patient outcome. For example, one of the touted goals of RSI is to blunt increases in intracranial pressure (ICP) from the ETI process, a relationship that has been described extensively in theoretical terms.[64] The use of defasciculating doses of paralytics has been prescribed for offsetting this theoretical effect.[65–67] While we know that succinylcholine can raise ICP, we have no knowledge of whether such rises are clinically relevant.[68] We also do not know whether laryngoscopy itself raises ICP or whether such occurrences are bad. There are also no clinical data formally linking succinylcholine use to ICP increase and subsequent adverse outcome in acutely head-injured patients presenting to the ED.[49,69] The same observations apply to the use of lidocaine to blunt response to laryngoscopy. While commonly practiced in the ED, the limited data on this topic are based on operating room patients.[70–75] There are no data formally supporting this practice in ED ETI.

Whereas there is a call to study the linkage between prehospital airway management and in-hospital outcomes, we have no knowledge of the linkage between ED airway management and in-hospital outcomes. The largest study of ED ETI to date is the National Emergency Airway Registry (NEAR), which has data for more than 10,000 ED ETIs.[58,76–78] While many interesting questions regarding ED ETI have been answered using NEAR, the registry lacks the most important component—linkage to in-hospital process of care and outcomes.

These observations reinforce the fact that despite the use of RSI in everyday ED practice, we actually have only a limited understanding of how this procedure works and of how it affects patients. Since we cannot determine whether RSI "saves lives" in the ED setting, it is impossible to determine (or speculate) whether RSI would "save lives" in the prehospital setting as well.

How Should We Use Prior Reports of Prehospital RSI?

Numerous published studies describe successful implementation of prehospital RSI. While the range and breadth of these reports are impressive, it is important to recognize the limitations of these prior reports. The majority of prior prehospital RSI studies used retrospective, single-site, descriptive designs with very limited sample sizes.[7,11,14,17–23,25,26,28,30,31,58,76–78] The majority of prior RSI studies have involved only air medical services, which are typically staffed with paramedics, nurses, and physicians who receive additional specialized training in critical care and airway management.[20] Therefore, it is impossible to generalize these findings to ground paramedic systems on a national basis.

Furthermore, there is currently no standard nomenclature for prehospital airway management, and thus it is difficult to compare airway-related outcomes and events. For example, there is no consensus on the definition of an ETI "attempt"—whereas most physicians consider an ETI attempt to consist of insertion of the laryngoscope blade, many EMS systems consider an ETI attempt to be an effort to place the endotracheal tube through the vocal cords.[79] This situation makes it difficult to compare—or even to pool together—results from multiple studies. To date there has been no formal meta-analysis of prehospital airway management.

Increasing emphasis has been placed on the relationship between prehospital interventions and in-hospital outcome.[80–84] In the EMS literature, only a handful of studies have connected prehospital ETI to the most important in-hospital outcome—death. The most well-known example connecting prehospital ETI to in-hospital outcome was reported by Gausche et al.[85] In this prospective controlled trial of conventional (non-RSI) pediatric ETI vs. bag–valve–mask (BVM) ventilation, the authors found no difference in mortality or neurologic outcome between the two techniques. Davis and colleagues' report from the San Diego RSI trial is the most prominent study linking prehospital RSI to in-hospital outcomes.[15] Future studies must endeavor to better link prehospital airway interventions to these important measures.

Several prior prehospital RSI papers deserve special comment. Wayne and Friedland reported the largest series of prehospital RSIs, including more than 1,600 paramedic RSIs performed over a 20-year period, a figure that eclipses almost all prehospital and ED RSI studies.[14] To achieve the same sample size today, one would likely have to perform a very large multicenter trial involving many EMS systems. Dunford et al. reported a subset of 54 patients from the San Diego RSI trial and found a high incidence (57%) of bradycardia and desaturation associated with the procedure.[16] The paramedics thought that the ETI was "easy" in 81% of these cases. The Dunford study is notable in that the use of automated data collection enabled formal depiction and analysis of the physiologic response to ETI. The study showed how it is possible to define the mechanistic aspects of the ETI process.

In 2001, the National Association of EMS Physicians (NAEMSP) published a position statement on prehospital RSI.[86] The paper outlines sensible standards for implementing prehospital RSI and was the end result of consensus opinions from many national leaders in prehospital airway management. The NAEMSP also recently published its recommended set of uniform guidelines for reporting data from prehospital airway encounters.[79] Widespread adoption of these standards would help to unify data collection and reporting standards and facilitate the potential pooling of airway management data. This would improve our ability to assess pressing questions regarding prehospital RSI.

Conclusions

Current data suggest that prehospital RSI is potentially useful in only a select subset of prehospital patients. The factors that impede prehospital ETI are not fully understood, and it is currently difficult to assess whether prehospital RSI would address these shortcomings. Whereas prehospital RSI was developed to mimic ED practices, we actually have a poor understanding of the process and effects of ED RSI. While there are multiple current studies of prehospital RSI, these studies are of limited utility. Future scientific efforts must endeavor to better define the mechanistic processes of RSI as well as to better link the procedure to in-hospital outcomes.

PREHOSPITAL RSI—DOES IT MAKE A DIFFERENCE?

The most compelling observations and questions emerge when prehospital RSI is linked to patient outcome. A growing body of evidence suggests that invasive airway management comes with a price that may outweigh any benefits with regard to oxygenation and airway protection. Thus, it may no longer be acceptable to simply arrive at the hospital with an endotracheal tube in place; instead, the means by which the ETI was achieved and the adverse physiologic conditions imposed upon the patient during the procedure may be more important. In fact, these results force us to ask whether early ETI itself is beneficial at all in any patient subsets.

In this section, we explore the evidence for and against early ETI in patients sustaining severe traumatic brain injury (TBI). We chose TBI for this discussion because the interactions (both theoretical and actual) between ETI and this disease process have been studied extensively. We also summarize the experience from the San Diego RSI trial, one of the largest and most controversial prehospital RSI studies. The outcomes analysis of this trial has sparked the most provocative questions regarding RSI and the airway management of severe TBI.

Evidence in Favor of Early Intubation for TBI

The earliest evidence supporting early ETI in head injury comes from a series of animal studies dating back to the 19th century. These studies observed that TBI was followed by a period of apnea directly related to the magnitude of the insult.[87–99] Thus apnea can produce death from asphyxia in the absence of pathologic evidence of traumatic injury.[92,94–96] These data are supported by human autopsy studies documenting hypoxic damage in patients who died from severe TBI. In addition, anecdotal evidence from series of nonaccidental trauma in children suggests a similar period of apnea following TBI in humans.[100,101]

Animal models of TBI also suggest that ventilatory support in the peri-injury period leads to recovery with minimal sequelae.[93–95] However, these animals were already intubated during application of the traumatic insult. Therefore, these studies did not directly evaluate the effects of the ETI procedure itself, which may offset the potential benefits of early ventilatory support.[93–95]

One of the primary arguments in favor of an aggressive approach to airway management involves the loss of airway reflexes, with a decrease in consciousness and the resultant risk of aspiration. Early support for this viewpoint came from a series of investigations documenting high aspiration rates in obtunded patients with postpartum hemorrhage and severe TBI.[87,102–110] Additional support was provided by documentation of a high incidence of "preventable" causes of death associated with a decreased level of consciousness in severe TBI, including aspiration and airway obstruction.[106–110] This was especially true in patients with lower injury severity scores (ISSs), suggesting that respiratory factors are responsible for deaths in otherwise salvageable patients.

In 1993, Chesnut et al. used a multicenter database to identify an association between prehospital hypoxia and increased mortality in severely head-injured patients.[111] The absolute mortality increase associated with hypoxia alone was only 1% but increased to 7% with concurrent hypotension. Several subsequent investigations confirming this association have been used to justify invasive prehospital airway management.[112,113]

Much of the evidence in favor of early ETI of severely injured patients comes from the air medical literature, which attributes at least part of increased survival to the advanced airway skills and improved ETI success rates associated with pharmacologically assisted ETI. Using the trauma and injury severity score (TRISS) methodology to calculate predicted survival, Garner zet al. observed a mortality decrease among patients treated by flight physicians as compared with an increase in mortality for a similar group of patients transported by ground paramedics.[114] Baxt and Moody found a decrease in both actual mortality and predicted mortality in patients treated by flight physicians and nurses as compared with those transported by paramedics.[115] Although the methodology was not intended to specifically investigate the effect of early ETI on outcome, the aggressive airway management strategies used by the advanced practitioners were cited as an important contributor.

Winchell and Hoyt's widely cited study is one of the few reports suggesting improved outcomes with paramedic ETI of severely head-injured patients.[116] In this retrospective analysis of 1,092 comatose blunt trauma patients transported in San Diego County, the authors observed a 21% absolute mortality benefit in favor of early ETI among patients with severe head injury [Glasgow Coma Scale (GCS) 3–8]. However, risk adjustment using multivariate regression techniques was not performed in this study. In addition, ETI rates were lower in the GCS 3 cohort, which is inconsistent with previous studies and suggests some hidden bias.

Surprisingly, few studies have explored the impact of aggressive in-hospital ETI on outcome. Trupka et al. compared in-hospital trauma patients requiring emergent (within two hours of arrival) ETI with those undergoing delayed (post two hours) ETI.[117] Rates of complications, including death, were significantly higher in the delayed-ETI group; however, the indications for ETI were dramatically different between the groups, making it difficult to draw meaningful conclusions about the impact of early ETI on outcome.

Evidence against Early Intubation for TBI

Recent data from animal models suggest factors that may account for some of the adverse effects of ETI on outcome.[118–125] Some animal models support the somewhat unconventional notion that hyperoxygenation may itself be detrimental, especially in the early phases of a cerebral insult.[126–128]

The importance of oxygen to cell survival and the association of hypoxia with increased mortality have led to the assumption that "more is better" and that maximizing serum oxygenation will lead to optimal salvage of injured brain. While this strategy is supported by the concept of ischemic zones that accompany severe head trauma due to edema, increased ICP, and vasodysfunction, hyperoxygenation may come at the expense of free-radical formation, which can exacerbate an existing brain injury.[126–129]

Despite evidence that apnea, airway obstruction, and aspiration are responsible for significant morbidity and mortality in TBI, most clinical data ironically do not support the early ETI of head-injured patients, especially when compared with noninvasive maneuvers such as BVM ventilation. It is not clear whether this reflects an increase in complications when less-experienced personnel perform the procedure or whether there is an inherent adverse effect of ETI and mechanical ventilation.

Eckstein and colleagues retrospectively identified 496 severely injured trauma patients who either were intubated in the field or required prehospital BVM ventilation and were intubated shortly after arrival at the hospital.[130] Improved outcomes were observed in the BVM patients, adjusted for age, gender, mechanism of injury, and GCS. Murray et al. studied 852 severely head-injured patients (GCS $\leq$ 8 and Head/Neck AIS $\geq$ 3) admitted to 13 different trauma centers.[131] A higher adjusted mortality was observed in patients who had a GCS score of 3 and in whom ETI was either successful or attempted. Adjusted risk of death was also higher in intubated patients versus those in whom ETI was unsuccessful or not attempted.

As discussed previously, Gausche and colleagues reported results from the only prospective, pseudorandomized trial to investigate the therapeutic effect of paramedic ETI.[85] In 830 children requiring ventilatory support, there was no statistically significant difference between the groups with regard to overall mortality or neurologic outcome.

The San Diego RSI Trial

The San Diego paramedic RSI trial was designed to explore the impact of succinylcholine-assisted ETI on outcome in severely head-injured patients. The results from this trial have been widely publicized and have raised provocative questions regarding not just prehospital RSI, but also the practice of prehospital ETI.

In this trial, adult head-injured patients with a GCS score of $\leq$8 were eligible, with paramedics first attempting ETI without RSI medications. Midazolam and succinylcholine were administered in the presence of intact airway reflexes or a clenched jaw; the Combitube (Kendall, Inc., Mansfield, MA) was used as a salvage device if ETI could not be accomplished within three attempts.

After the first trial year, the initial analysis revealed an ETI success rate of 84%, with Combitube insertion successful in an additional 15% of trial patients.[17] This resulted in a total of only 14% of all trauma patients with a GCS score of $\leq$8 arriving in the ED with an unsecured airway; this figure compared with 61% during the preceding year.[10] Interestingly, the percentage of patients intubated without medications was higher during the trial year (20% vs. 12%), likely reflecting an increased emphasis on the importance of early ETI.

Despite the apparent improvements in airway management success, the initial outcomes analysis suggested an adverse effect of RSI on outcome.[15] Each trial patient was hand-matched to three nonintubated control patients from the county trauma registry based on the following criteria: age, gender, mechanism of injury, ISS, and Abbreviated Injury Scale (AIS) values for Head/Neck, Chest, Abdomen, Extremities, and Skin. Patients who did not survive the initial resuscitation or whose Head/Neck AIS score was defined by a neck injury were excluded from both groups. The trial patients and control patients were identical with regard to all matching criteria, the incidence of invasive procedures, vital signs on arrival, and head injury diagnosis (contusion, subdural hematoma, epidural hematoma, subarachnoid hemorrhage, cerebral edema, or skull fracture). Mortality was significantly higher in the RSI cohort for all patients (33% vs. 24%) and for those with severe head injuries as defined by a Head/Neck AIS score of $\geq$3 (58% vs. 46%). Multivariate logistic regression confirmed the independent adverse effect of RSI on outcome, adjusted for age, gender, Head AIS, Chest AIS, Abdomen AIS, admission systolic blood pressure (SBP), and scene time. In light of these data, the trial was suspended. A subsequent analysis of the entire cohort of trial patients has confirmed these results.

Suspected Reasons for the Observed Results

In the wake of these somewhat unexpected results, the challenge has been to determine whether the increase in mortality associated with paramedic RSI represents a methodologic flaw, suboptimal performance of the procedure by inexperienced personnel, or an adverse effect of ETI and positive-pressure ventilation in general. While the potential for selection bias introduced by the nonrandomized design certainly exists, *post hoc* analyses have suggested several factors that likely played a role in the outcome of head-injured patients intubated in the field.

While hyperventilation has been used routinely for many years to control ICP, recent data have indicated adverse effects from this technique.[132–134] During the trial, one agency instituted the use of quantitative end-tidal carbon dioxide ($ETCO_2$) monitoring and documented hyperventilation ($ETCO_2$ < 30 mm Hg) in 79% of patients and severe hyperventilation ($ETCO_2$ < 25 mm Hg) in 59%. Logistic regression confirmed increased mortality among those experiencing hyperventilation, adjusted for age, gender, initial SBP, Head/Neck AIS, and ISS. Use of $ETCO_2$ monitors was observed to decrease the incidence of inadvertent hyperventilation. The only RSI subgroup without increased mortality included patients who underwent paramedic RSI but were then transported by air medical crews, personnel who had substantial experience using $ETCO_2$ to guide ventilation.

Although an association between hypoxia and adverse outcomes has been established, the effect of transient hypoxia during ETI is not well studied. Manley et al. observed a 38% incidence of desaturations (SaO_2 $\leq$92%) in trauma patients during trauma resuscitations but were unable to demonstrate an impact on survival.[135] As discussed previously, desaturations were observed in more than half of a subset of 51 patients, and an increase in mortality was associated with deep desaturations.[16,136,137]

An important principle in prehospital care is the rapid transport of critically injured patients to the hospital for definitive care. Transportation delays have been associated with increases in morbidity and mortality.[138,139] Thus, there is essentially a cost–benefit ratio for every prehospital intervention performed on scene. ETI can add valuable minutes to the total prehospital time, especially with the use of RSI. In the San Diego paramedic RSI trial, the procedure was performed on scene in two-thirds of patients, which added approximately 15 minutes to the scene time.[17]

It is also possible that aspiration—before or after the RSI—may have affected patient outcome. Prior studies suggest that aspiration may occur immediately following the onset of injury and prior to the arrival of prehospital personnel.[106–110] During the trial paramedics reported clinical evidence of aspiration (defined as the presence of blood or vomitus beyond the vocal cords, or the presence of oropharyngeal blood or vomitus and rhonchi on pulmonary examination) in almost 25% all patients.[17] However, none of these was reported as a direct consequence of the RSI procedure. The rate of aspiration pneumonia was higher in RSI patients versus their matched controls. It is conceivable that the ETI procedure itself introduced oropharyngeal contents into the trachea.

An important question that was raised was whether the inclusion criteria for applying RSI were appropriate and correctly followed. Anecdotally, many EMS directors express the concern that in the hands of inexperienced personnel, RSI may be used inappropriately on prehospital patients who do not truly require the procedure. The basic inclusion criteria for the San Diego RSI trial consisted of TBI patients with GCS score ≤8. Extensive efforts were made during training to ensure that paramedics could rapidly and accurately determine the GCS score. No significant error in GCS calculation was detected during the trial.

In retrospect, it is not clear whether the use of the GCS score as the primary selection criterion was the ideal approach. A fourth of the enrolled patients did not have significant head injuries at all, but had merely suffered a transient loss of consciousness and returned to baseline upon arrival at the trauma center.[15] This should not be surprising since in the setting of TBI, frank apnea or hypoventilation may not be present. The clinical decision to apply RSI in these patients may be based upon the alteration of mental status and the perceived inability to control the airway or ventilation. While we embrace these clinical findings in defining protocols and criteria for RSI, the fact remains that this decision process is probably oversimplified. A future effort must be conducted to identify more accurate decision pathways for RSI application. It is likely that such a decision process will invoke physiologic, anatomic, and clinical parameters not currently considered in airway management.

Finally, the training provided to the paramedics in the trial may be scrutinized. The level of initial and ongoing training required to safely perform ETI using neuromuscular-blocking agents has not been adequately defined. In the San Diego RSI trial, paramedics received a single seven-hour mannequin-based training session—operating room training was not used. However, many prior studies used supplemental airway training, including the use of operating room time, as part of their RSI program.[7,14,20,27,28,31,140–144] The relationship between ETI training and clinical skill is an area that merits future study.

Lessons Learned from the Trial

While the trial uncovered several worrisome findings, many important lessons were learned from this effort. First, advanced monitoring including pulse oximetry and end-tidal capnography should be mandatory when performing ETI with or without RSI. Second, adequate preoxygenation prior to RSI and close oxygen saturation monitoring during laryngoscopy should be routine. Third, hyperventilation should be avoided, and consideration should be given to incorporating noninjurious ventilation strategies into prehospital care. The trial also highlighted gaps in current scientific knowledge regarding the appropriate selection criteria for RSI and appropriate training for paramedical personnel performing RSI.

We see the results of the trial in a positive light. Despite the wide array of scientific reports describing prehospital RSI, the important issues that surfaced during the San Diego RSI trial have never previously emerged. We believe that there will be an expanding role for prehospital RSI in the future. Lessons learned from the trial will help lead to a safe and effective recipe for prehospital RSI.

Conclusions

While experimental models and our current understanding of the pathophysiology of TBI support a more aggressive approach to early airway management, clinical data suggest a detrimental effect of early ETI and positive-pressure ventilation in these patients. The risk of aspiration and hypoxia must be weighed against potential adverse effects of ETI and ventilation. Findings from the San Diego RSI trial have provided valuable lessons for the implementation and process of prehospital RSI.

BELLINGHAM, WASHINGTON—A PREHOSPITAL RSI SUCCESS STORY

In the United States, nonphysicians provide most out-of-hospital care—the airway needs of patients are the same no matter who is providing that care. At Whatcom Medic One (WMO), the integrated ALS service of the City of Bellingham and Whatcom County, Washington, it is believed that with proper education and involved medical direction, nonphysicians can be trained to perform physician-level airway management. WMO believes that excellence in airway management skills, and the knowledge that goes with it, "trickles down" to affect all aspects of prehospital care. The service believes that its prehospital RSI program is ideal and has resulted in excellent clinical results. The RSI program is based on not only existing scientific evidence, but also the system's vast prior clinical experience.

The City of Bellingham and Whatcom County, Washington, comprise the northwestern-most county in the continental United States. The system covers an area of more than 2,200 square miles and is bordered by the U.S.–Canadian border, the Pacific Ocean, and the Cascade Mountains. A static and transient population of approximately 225,000 is served. The EMS system of Bellingham and Whatcom County consists of an integrated basic life support (BLS) and ALS system that is fire department–based. BLS providers from 17 county fire districts and the City of Bellingham Fire Department provide first response. Countywide ALS response is from full-time Bellingham Fire Department–based paramedics.

How are Paramedics Trained in Prehospital RSI? What Concepts are Emphasized?

Prehospital RSI may be taught and performed using many different models. WMO has chosen to emphasize common elements of those models in its system. While the scientific evidence many be lacking for some of these elements, WMO believes that the elements work well in clinical practice for its system. The system design and methods for using RSI comprise an example only—individual medical directors and systems must consider whether these strategies are in fact ones that they wish to adopt and implement. It should be acknowledged that WMO adheres to a standard of education and skills maintenance that may not be achievable by all ALS services.

WMO trains its paramedics through a local, nationally accredited paramedic training program consisting of more than 1,800 hours of didactics and skill training.[145,146] As a part of this education, the airway management component is made up of 20 hours of classroom education incorporating video instruction, competency testing on medication knowledge, and mannequin simulation. While Dr. Wayne originated the training program 30 years ago and serves as its medical director, a committee oversees the program and establishes training standards. This is done in concert with the national curriculum for training of emergency medical technicians–paramedics (EMT-Ps).[146] RSI training has been a standard part of the curriculum from the second year of the program in 1976.

After successful completion of the classroom portion, the student performs a minimum of 20 human ETIs in the operating room (OR) under the guidance of board-certified anesthesiologists. WMO believes that this commitment by the anesthesiologists is a key component of its successful training program and the competency of its graduates. Not only does this approach ensure live human ETI experience, but it also affords exceptional training and teaching by airway management masters. WMO believes that newer human airway simulators offer supplemental educational experiences in airway management but do not serve as a substitute for the "live" OR experience.

After the OR time has been completed, the student spends three months riding on a medic unit as a third medical provider. Once graduated, the certified paramedic must perform one human ETI per month for the first three years of certification (12 ETIs per year), then one per quarter thereafter (four ETIs per year). In addition, all paramedics must participate in an annual airway maintenance and skills laboratory. Recently, Washington State law was modified to allow some of this mandatory ETI experience to be accomplished via human simulation. WMO has not accepted this standard because of its belief that intubation skills for paramedics performing RSI must be superb, and that human simulators or mannequins do not provide acceptable alternatives for assessing excellence in ETI skill. While WMO may modify its position after gaining more experience with human simulators, current scientific data do not support such a change.

When WMO began its program in 1976, it was modeled after an already established RSI program in Seattle's Medic One program. Through the ensuing years Whatcom has modified that program's tenets to its current standards:

1. Excellent patient assessment and basic airway skills.
2. Emphasis on recognizing when to progress from basic to advanced airway management techniques.
3. Once committed to providing an advanced airway, recognition of when to add a paralytic and other medications.
4. A comprehensive knowledge of the pharmacology of all RSI medications, including indications, contraindications, actions, side effects, and associated complications.
5. The use of a full complement of monitoring devices, including pulse oximetry, end-tidal capnography, and endotracheal tube aspiration devices (esophageal detector devices) to ensure the placement and continued retention of the endotracheal tube within the trachea.
6. When ETI cannot be achieved, the use of rescue airway devices such as the Combitube or percutaneous cricothyroidotomy, both of which are standard equipment on all ALS units.

While there are no nationally defined indications for the use of RSI in the field, WMO believes that RSI is indicated for any patient in whom there is a need to control an "uncontrolled" airway. This may include depressed GCS score, excess secretions, hypoxia that may be correctable, ventilatory fatigue, or central nervous system depression with or without secondary respiratory depression.

WMO teaches the actual procedure of RSI using a "five Ps" paradigm: 1) preparation, 2) preoxygenation, 3) pretreatment, 4) paralysis, and 5) pass and confirm the tube. Under certain circumstances, one or more steps may be abbreviated. For example, additional sedation after ETI may be needed for those who still retain some degree of masseter spasm or gag reflex. "Preoxygenation" should never be excluded.

The system uses succinylcholine at a dose of 1.5 to 2 mg/kg as a primary paralytic agent. While fasciculations may theoretically be blocked by pretreatment with a nondepolarizing agent, Whatcom does not incorporate this procedure because 1) this adds another medication, necessitating additional knowledge and time to administer, and 2) the observed fasciculations help the paramedic to identify the onset of drug effect. Although the value of the practice has been questioned, the system currently pretreats head-injured patients with IV lidocaine.[69,70,73,75] All patients less than 8 years of age with atropine are pretreated because of succinylcholine's recognized bradycardic effect on this age group of patients. Atropine is administered for all ages before any supplemental dose of succinylcholine as well as for any patient with unexpected bradycardia. The system uses midazolam 0.05 mg/kg and/or morphine 0.05–0.1 mg/kg to provide amnesia and sedation.

While nondepolarizing paralytic agents such as rocuronium have been considered for prehospital RSI, WMO does not use these agents because they have not met the system's criteria for 1) speed of onset, 2) short duration, 3) predictable clinical effects and side effects, and 4) reasonable cost.

As previously noted, WMO emphasizes tube confirmation and continuous monitoring using state-of-the-art mainstream, waveform capnography and continuous pulse oximetry. In cases where there are doubts about the accuracy, or where equipment failure occurs, an esophageal detector device (EDD) is added as a backup. Other tube-confirmation methods (such as auscultation and physical examination) do not provide the necessary accuracy to ensure intratracheal placement and maintenance of that placement. Previously published work from the Orlando, Florida, area supports this position.[147]

What are the Results?

The results of this program speak for themselves. WMO previously reported the results of its RSI program in 1999.[14] Since that time, the system has accrued data describing a total of 2,978 patients. Of these, 96.6% were intubated within one to three attempts. All unsuccessful ETIs were effectively managed with alternative airways or BVM ventilation.

Very few adverse events have been observed. One unexpected death, from hyperkalemia, occurred in a patient with unknown amyotrophic lateral sclerosis. There were 48 cases of aspiration after the administration of succinylcholine; the significance of these events with regard to patient outcome has been difficult to evaluate. Prior to 1990 there were six unrecognized esophageal ETIs. Since the institution of a tube-confirmation pathway in 1990 (which mandated the use of waveform capnography), there has been only one unrecognized esophageal ETI. In this patient the absence of $ETCO_2$ was noted, but an alternative device was not used to confirm intratracheal tube placement. This failure was addressed through WMO's education program and the continued close monitoring of RSI use by the paramedics. In general, the system emphasizes the use of an alternate tube confirmation device or the performance of repeat direct laryngoscopy whenever the mainstream capnograph has a mechanical failure or displays a questionable reading.

WMO has not observed problems with desaturation and bradycardia as reported in the San Diego RSI trial.[16] This may be due to Whatcom's strong emphasis on preoxygenation (via BVM ventilation) prior to any second or subsequent ETI attempt. Also, the system has established a culture of open communication between members of the RSI team. If an adverse event is observed (such as a prolonged ETI attempt or desaturation), members of the team are responsible for communicating this observation to the individual attempting the ETI.

WMO has had RSI experience in pediatric patients less than 15 years of age. Prehospital RSI has been used on 131 patients aged 11 months to 15 years (mean 7.8 ± 2.8). These patients included 92 trauma cases and 39 medical cases. The overall success rate for RSI in this age group was 97.6%. Prior to the institution of the tube confirmation pathway, noted above, two unrecognized esophageal ETIs occurred in this subset. Since institution of that pathway, none has been documented by either an ED physician or the medical examiner.

Conclusions

WMO has a successful and safe prehospital RSI program because of its unique training experience and stringent attention to quality. A comprehensive didactic training program is supplemented with hands-on OR-based airway training. Whatcom adheres to strict standards for the numbers of ETI required of each paramedic. The system has invested in and requires the use of state-of-the-art continuous $ETCO_2$ monitoring, which is an important safety feature of a prehospital RSI program. Most importantly, strong, committed medical direction with close systemwide monitoring may be the most important ingredient of the program's success.

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