Emergency Tracheal Intubation: Techniques and Outcomes

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Performing emergency endotracheal intubation necessarily means doing so under less than ideal conditions. Rates of first-time success will be lower than endotracheal intubation performed under controlled conditions in the operating room. Some factors associated with improved success are predictable and can be modified to improve outcome. Factors to be discussed include the initial decision to perform endotracheal intubation in out-of-hospital settings, qualifications and training of providers performing intubation, the technique selected for advanced airway management, and the use of sedatives and neuromuscular blocking agents. *Key words: emergency treatment; equipment and supplies; laryngoscopes; respiration, artificial; respiratory therapy; resuscitation.* [Respir Care 2014;59(6):881–894. © 2014 Daedalus Enterprises]

Introduction

Emergency endotracheal intubation will always be necessary because we cannot predict when accidents or emergencies will occur. Even in the hospital, despite advances in monitoring and management, the need for urgent or emergent endotracheal intubation occurs with regular frequency. The procedure is made difficult because usually there is no time for a detailed history and physical exam-

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Table 1. Common Problems Associated With Emergency Endotracheal Intubation

Limited ability to examine the airway
Limited equipment and positioning
Limited back-up
Difficult, often inadequate pre-oxygenation
Presence of co-existing life-threatening conditions

ination or discussion and planning among the health care team (Table 1). Some factors, however, are predictable and can be modified to improve the likelihood of success and a favorable outcome.

Location

Prehospital

Reasonable controversy exists as to what, if any, prehospital advanced airway management should occur in patients requiring respiratory support. The best advanced airway to use is also a matter of debate. Clearly, some of this decision making depends upon the personnel available, their level of experience, and their familiarity with emergency airway management.

Most of the studies on prehospital airway management are with patients suffering out-of-hospital cardiac arrest (OHCA). The outcomes that have been examined include return of spontaneous circulation (ROSC), neurologic sequel survival to hospital admission, survival to hospital discharge, and ease and success of airway placement.[1-11]

Success With Endotracheal Intubation. Studnek et al[9] retrospectively studied 1,142 OHCA subjects to determine whether the type of airway management chosen influenced the rate of ROSC. They also evaluated the success and frequency of different types of airway management. Fifty percent of subjects were successfully intubated on the first attempt; 26% had more than one attempt at intubation (12% of the total population was successfully intubated with multiple attempts; 14% were unable to be intubated despite multiple attempts); 18% did not have any attempt at intubation; and the remaining 6% had one attempt at intubation that was a failure, with no further attempts made.[9] Unfortunately, the study did not examine how responders made decisions regarding whether to attempt intubation. The causes of failed attempts, whether it be inadequate exposure, inability to use medications to facilitate intubation, or other reasons, were also not examined.

There is no benchmark for success of prehospital intubation that would help interpret these numbers. Certainly, it would be inappropriate to judge success rates against intubation of relatively healthy patients in the operating room. A more reasonable comparison might be intubations performed in the emergency department (ED), although this setting still provides more favorable conditions for successful intubation than a prehospital setting. In a group of 314 trauma subjects, the success of endotracheal intubation in the field and in the ER was similar: 83% were intubated in the field on the first attempt, and 86% in the ED. Only 2% of the field intubations and 1% of the ED intubations required as many as 4 attempts.[8]

Return of Spontaneous Circulation. The occurrence and time elapsed before ROSC are important outcomes of the management of patients with OHCA. One of the more robust studies examined 649,359 OHCA subjects in Japan; 57% of the subjects were managed with bag-mask ventilation (BMV), and 43% had an advanced airway placed (6% of total enrolled subjects had an endotracheal tube (ETT) placed; 37% received a supraglottic airway). The subjects who had an advanced airway placed had lower rates of ROSC compared with those transported with BMV alone (7.0 vs 5.8%, $P < .001$).[2] In the report by Studnek et al,[9] using BMV and not attempting intubation were associated with an adjusted odds ratio (OR) of 2.33 in achieving ROSC (adjusted for first rhythm) compared with subjects who were intubated on the first attempt. Perhaps since ROSC is dependent upon the patient receiving high-quality and consistent chest compressions, interruption of compressions during intubation and distraction of health care providers during the procedure may be responsible for the poorer outcomes.

Not all studies, however, are in agreement with this point. Nagao et al[7] examined 355 OHCA subjects and reported higher rates of ROSC in subjects with advanced airways placed compared with BMV management (18.6 vs 10.3%, $P = .035$). Likewise, studying 2,586 OHCA subjects, Takei et al,[10] reported increased rates of ROSC in those subjects managed with an ETT compared with advanced airways other than an ETT and those managed with BMV alone (30.0, 20.2, and 21.3%, respectively, $P = .003$).

Neurologic Outcome. Hasegawa et al[2] reported that 1-month neurologic outcomes for OHCA subjects were more favorable in patients managed with BMV alone (2.9%

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of total OHCA subjects) compared with advanced airways (1.1%), although both are abysmally low rates. They concluded that the use of both ETT and supraglottic devices was an independent predictor of untoward neurologic outcome.

Survival and Hospital Discharge. Several studies have examined the influence of prehospital airway management on survival following various time periods. In the study by Hasegawa et al[2] of OHCA subjects in Japan, those managed with BMV had a 1-month survival of 5.3% compared with 3.9% for those managed with an advanced airway. Studnek et al[9] reported an increased rate of survival to hospital discharge in OHCA subjects managed with BMV only compared with those who were intubated on the first attempt. The literature remains divided, however, on this point, with some researchers reporting no difference with airway management between survival at 1 month and at 1 year[10] and others reporting a nonstatistically significant trend toward improved survival to hospital discharge in patients receiving advanced airway management.[7]

In a subgroup of patients suffering from severe traumatic brain injury, defined as having a Glasgow coma scale score of < 8, there are unclear data regarding how the choice of whether to intubate impacts survival.[12] There is, however, virtually universal agreement that optimizing oxygenation and ventilation of these patients in a prehospital setting has a clear effect on survival.[13-16] Despite the fact that temporary hyperventilation has been shown to acutely decrease intracranial pressure in some circumstances,[17] there appears to be less benefit in traumatic brain injury patients, and in fact, P_{aCO_2} levels below 30 or 35 mm Hg (depending upon the study) as well as above 45 mm Hg are associated with significant increases in mortality.[13,14,16]

Recommendations. The data on prehospital advanced airway management are not clear-cut. Most of the studies are of OHCA patients and might not be applicable to other patient populations such as trauma patients. The data for type of airway management and achievement of ROSC are particularly conflicting, although the most robust study favors BMV and not use of an advanced airway.[2] There seems to be a survival benefit for use of BMV only (in OHCA patients) in multiple studies. There may be improved neurologic outcome in patients who are not managed with an advanced airway as well. Overall, the data seem to favor avoiding advanced airway management in OHCA patients and instead focusing on high-quality chest compressions. On face validity, it is reasonable to conclude that if there is no effective circulation, ventilation of the lungs is irrelevant. Furthermore, in low cardiac output states, increased intrathoracic pressure produced by positive-pressure ventilation may impede venous return and worsen the low-flow state.

The American Heart Association updated the guidelines for advanced cardiac life support in 2010. Their statement regarding advanced airway management points out that "there is no evidence that advanced airway measures improve survival rates in the setting of out-of-hospital cardiac arrest."[18] More recent evidence continues to support this conclusion.[2] In the absence of specific indications to secure an advanced airway, the evidence favors mask ventilation alone in this setting.

Emergency Department

Walls et al[19] set out to better determine the characteristics of intubations in the ED in terms of indications, techniques, rates of success, and unplanned events in a multi-center study that included 31 EDs and 8,937 subjects over a period of 5 y. Most of the subjects presented with medical rather than traumatic problems, and most were intubated using rapid-sequence intubation (RSI; 69% of all subjects and 84% of subjects who received medications to facilitate intubation). The first-attempt success rate was 95%, and 99% of subjects eventually received a successful procedure. Regrettably, descriptive details were unavailable for the 1% who were not successfully intubated. The authors postulated that these subjects may have expired when resuscitation efforts ceased. Emergency medicine physicians performed 87% of these intubations, anesthesiologists performed 3%, and the remaining 10% were performed by various other specialists.[19]

When specifically considering failed attempts at intubation, Bair et al[20] analyzed the National Emergency Airway Registry database to examine the prevalence of failed airway management in the ED. Failed airway management was defined as an unsuccessful first attempt that subsequently required a rescue maneuver. Of the 7,712 subjects who were emergently intubated during the 3 years they examined, 3% had failed attempts. Interestingly, 49% of subjects who had a failed first attempt did not initially receive an RSI and had RSI performed as the rescue technique. Twenty-one percent of subjects with failed attempts received emergent surgical airways; half of these were performed by emergency medicine physicians.[20]

Emergency medicine physicians are clearly able to establish emergency airways in the vast majority of circumstances and should certainly continue as the first line of airway management in the ED. In the few cases in which they are unsuccessful, it remains appropriate to consult other physicians with expertise in airway management, be they anesthesiologists, surgeons, or otolaryngologists.

ICUs

The ICU setting offers similar challenges for emergency intubation as the ED. Literature regarding emergency intubation in the ICU focuses largely on complications and interventions to minimize them, more so than rate of success or failure. Compared with elective intubation of patients in the operating room, inadequate pre-oxygenation[21] and limited ability to examine the airway in preparation[22] seem to be two of the biggest issues. Mort[21] suggests that pre-oxygenation with BMV (to provide positive pressure-assisted breaths) is superior to that with patient-driven negative-pressure ventilation. Another option that accomplishes the same goal is the use of noninvasive ventilation with 1.0 F_{IO_2}. This is particularly useful when a patient is already receiving noninvasive ventilation pre-intubation.

Personnel

Prehospital Providers

Most health care systems in North America use non-physician providers to staff their emergency medical systems. Outside of North America, the vast majority of emergency medical staff are physicians.[23] In a recent meta-analysis, Lossius et al[5] examined whether the type of provider impacted the decision to intubate, the technique used, and the rate of success. They concluded that physicians had a higher rate of success for emergency intubation (median of 99.1% compared with 84.9%). Interestingly, they noted that all of the physician-run emergency medical services had analgesic, anesthetic, and paralytic drugs available, whereas only 50% of the non-physician groups had drugs including paralytics, 23% had analgesics and sedatives but no paralytics, and 27% had no intubation medications available. The non-physician group without medications available had the lowest rate of success at intubation (median of 67.5%).[5]

Respiratory Therapists

It is a logical choice that respiratory therapists perform endotracheal intubation because they are skilled in treating respiratory distress and are typically present at the time of intubation when performed out of the operating room. Bishop et al[24] examined the process of training respiratory therapists to perform endotracheal intubation and specifically examined retention of skills 1 year after training. They reported that performing endotracheal intubation only occasionally was inadequate for maintenance of skills. Performing well on a written test about intubation was associated with performing intubation more effectively.[24]

Pulmonologists

Internal medicine training, at least in the United States, has little focus on airway management despite the fact that many rapid response and code blue teams are staffed by internists. Fellowship training in pulmonary and critical care medicine involves more training in airway management, although there is no formal or standardized curriculum. In the study by Vianello et al[25] on pulmonologist management of emergency intubations in a respiratory ICU, each pulmonologist received an individual training program that consisted of shadowing an anesthesiologist for 3 months. The pulmonary physicians were expected to perform 40 intubations during this time. To maintain their skills, they were also expected to perform 15 intubations every year in the operating room. They concluded that pulmonary physicians trained in intubation had a high rate of success; only 3 of 46 intubations required the assistance of an anesthesiologist or fiberoptic intubation.[25] One might hypothesize that anyone who is held to such rigorous standards for training and maintenance of competence would be likewise successful; the question would be how many providers would be able (or willing) to commit to such a rigorous program.

Attending Presence in Teaching Hospitals

Schmidt et al[26] studied emergency intubation in their hospital. Emergency intubations were usually performed by anesthesia residents on their surgical ICU rotation; standard practice in their ICU did not require supervision by an attending anesthesiologist. When an attending anesthesiologist was present, complications of intubation, such as esophageal intubation, traumatic intubation, aspiration, dental injury, and endobronchial intubation, occurred in 6% of patients compared with 21% of intubations that were not immediately supervised ($P = .001$).[26] Although both opioids and paralytics were more commonly administered when attending anesthesiologists were present, only attending presence and not the use of medications was statistically associated with improved outcome upon multivariate analysis.

Recommendations. The main similarity connecting all of these studies is that with adequate training in intubation and maintenance of competency, health care providers from many backgrounds are able to perform emergency endotracheal intubation safely. Several of the studies specifically trained providers to perform intubation in operating rooms under ideal conditions and under the supervision of anesthesiologists. Although it was not explicitly studied, it seems reasonable to conclude that it is not optimal to attempt to learn *how* to perform endotracheal intubation in emergency and uncontrolled situations, in which there is

little room for error. It appears prudent to consider incorporating supervised practice in the operating room and/or under simulated conditions when teaching endotracheal intubation so that learners may safely acquire this skill under calm conditions.

Techniques

Direct Laryngoscopy

Direct laryngoscopy (DL) remains the standard tool for performing endotracheal intubation. Few studies have evaluated the use of DL for intubation. In fact, studies using other methods such as video laryngoscopy (VL) have compared the ease and success to that with DL. Delaney et al[27] performed an interesting study on intubating unconscious soccer, football, and ice hockey athletes. They found that using a laryngoscope with a shorter handle (10.8 vs 15.2 cm) was easier in the athletes, especially hockey and football players, who were often still wearing protective gear. Anecdotally, this seems to be true in morbidly obese patients, who, without an adequate ramp under their shoulders, often end up with their necks flexed with minimal physical space for the handle to occupy over their anterior chests while attempting to insert the laryngoscope into their mouths.

Video Laryngoscopy

VL is the major alternative to DL. One could also consider fiberoptic intubation; however, this technique is typically more time-consuming and is therefore a poor choice in emergency situations, except for patients with severely abnormal airway anatomy. When it comes to VL, there are many options, which fall into 3 basic categories: fiberoptic stylets, guide channel devices, and video modifications of direct laryngoscopes. When considering VL as opposed to DL, there are several important factors to evaluate, including ease of use/learning curve; size and location of the viewing screen; size and maneuverability of the device; whether it has anti-fog technology; battery life and power source; and whether sterile processing is required.[28]

Studies comparing the use of DL with VL have reached differing conclusions. Guyette et al[29] showed equal success at intubation with a Macintosh direct laryngoscope compared with a C-MAC laryngoscope (Karl Storz GmbH & Co KG, Tuttlingen, Germany) in terms of number of attempts, although often with improved Cormack-Lehane views with the C-MAC. Sakles et al[30] compared the C-MAC with the Macintosh direct laryngoscope for ED intubations and reported an increased rate of grade 1 and 2 views as well as an increased success rate for intubations with the C-MAC (OR 3.4 for successful intubation compared with DL).

When comparing the GlideScope (Verathon, Bothell, Washington) and Macintosh direct laryngoscopes used by providers with limited intubation experience (mannikins only), the GlideScope had a higher rate of success (90 vs 50%) than a Macintosh blade.[31] In subjects with predictors of difficult intubation in the ED (including obesity, large tongue, short neck, small mandible, cervical spine immobility, blood or vomit in the airway, airway edema, or trauma to the face or neck), Mosier et al[32] evaluated the efficacy of the GlideScope versus a direct laryngoscope and reported an increased rate of first-time success with the GlideScope (overall OR 2.2). The GlideScope was superior in subjects with small mandibles (OR 2.93), blood in the airway (OR 2.79), large tongues (OR 1.9), and obesity (OR 1.6). The use of the rigid stylet made by Verathon also improved success of first-time intubation with the GlideScope compared with a malleable stylet.[33]

Guide channel devices include the AirTraq (Airtraq, Bonita Springs, Florida), Pentax-AWS (Ambu, Glen Burnie, Maryland), and Res-Q-Scope (Res-Q-Tech, Humble, Texas). One study reported that use of the AirTraq reduced movement of the cervical spine compared with DL using a Macintosh laryngoscope and suggested that when cervical spine movement is undesired, the AirTraq may be a good choice.[34] Suzuki et al[35] found that when using the Pentax-AWS, both the rate of success and the time to intubation were improved by using the scope with a Parker Flex-Tip endotracheal tube (Parker Medical, Highlands Ranch, Colorado).

Use of VL facilitates intubation by providers with limited experience as well as by experienced providers caring for patients with anticipated difficult airways. Most of these devices have been compared using a Macintosh blade for DL. It is unclear if the benefits in these studies would remain similar or change in magnitude if comparisons were made using a Miller blade or other DL blades.

Blind Nasal Intubation

Orotracheal intubation is but one option for securing an airway. Although not performed frequently anymore, blind nasal intubation is another option in the event of an emergency. van Elstraete et al[36] reported that by using a technique of (1) inflating the ETT cuff once they entered the oropharynx (which was judged by loss of resistance to tube advancement); (2) keeping the cuff inflated until they met resistance, indicating that the tip was at the vocal cords; and (3) deflating the cuff, advancing through the cords, and then re-inflating, they were more successful on the first attempt (95 vs 45%). Blind nasal intubation may not be appropriate in the setting of facial trauma, as there is an increased risk of passage into a false tract. Long-term nasal intubation also may increase the likelihood for sinusitis.

Supraglottic Devices

Supraglottic airway devices are an increasingly popular alternative to endotracheal intubation for emergency airway management. Most available studies of these devices are in the setting of elective surgery or difficult/failed intubation. One study of the King LTS-D airway (Kingsystems, Noblesville, Indiana), a combination esophageal-laryngeal tube, compared its use with an ETT in a prehospital setting. Both devices had essentially the same rates of successful placement (80%) and took approximately the same amount of time to place (20 s).[37] Rabitsch et al[38] evaluated a combitube (Mallinckrodt esophageal tracheal airway double-lumen tube, Covidien, Mansfield, Massachusetts) in a prehospital setting in cardiac arrest subjects and reported a rate of first-attempt success of 98%; for endotracheal intubation, it was 94%. They suggested that the combitube is superior in settings in which it is hard to get to the subject's head or when the subject has blood or emesis in the airway. Another study compared the rates of successful placement during cardiopulmonary resuscitation by ICU nurses placing combitubes versus intensivists performing endotracheal intubation and concluded that it took less time for the nurses to place combitubes (18 vs 27 s) with equal success.[39]

Supraglottic devices such as the laryngeal mask airway function to support the airway without the difficulty of maintaining a seal with face mask for BMV. These devices allow for ventilation delivered directly to the glottic opening, bypassing redundant tissue as is present in obese patients or patients with obstructive sleep apnea. They are placed blindly, are able to be seated adequately in most people, and can be used as an adjunct to help facilitate endotracheal intubation. The major disadvantages of laryngeal airways are their relative inability to protect against insufflation of the stomach if high airway pressures are used and aspiration of gastric contents.[40]

Recommendations. The type of airway to use and technique for its placement should be based largely on the skill set of the provider managing the airway. Studies support the use of supraglottic devices such as the laryngeal mask airway and combitube even by providers with minimal experience in their use. In providers experienced in airway management, endotracheal intubation is preferred. The choice in that instance between DL and VL should be made based on the patient's airway and predicted difficulty in intubation. VL is preferred for patients in whom endotracheal intubation is predicted to be difficult.

Medications

Use of medications to facilitate intubation is appropriate in settings where the patient is alert or is expected to have intact airway reflexes. Patients who are in the midst of a cardiac arrest usually have neither and may not require medication-assisted intubation. The next section focuses on patients who require urgent and emergent intubation in clinical scenarios other than cardiac arrest.

Sedatives and Anesthetics

Etomidate. Controversy surrounds the choice of sedatives and anesthetic medications in the setting of emergency intubation. Etomidate is a popular choice given its minimal effects on hemodynamics. However, concerns regarding adrenal suppression with even a single dose of etomidate and the ongoing question of the clinical importance of this depression have placed the use of etomidate in the spotlight. It is clear that a single dose of etomidate will inhibit 11β-hydroxylase (a key enzyme in steroid synthesis) within the adrenal cortex for a duration of anywhere from 6 to 48 h.[41] Several studies have examined the effect of a single dose of etomidate administered to critically ill subjects.[42-44] It appears that the only point of agreement in all of these studies is that patients with septic shock are at risk for clinically important adrenal suppression from a single dose of etomidate. The most recent meta-analysis concluded that there is no increased risk of mortality in septic shock patients receiving etomidate.[45] However, this analysis was published shortly after another meta-analysis, published in the same journal, concluded that etomidate use with RSI in septic shock patients was associated with increased rates of adrenal insufficiency and mortality.[42] It remains difficult to form firm conclusions on the use of etomidate. In this setting of controversy, a logical and reasonable conclusion was reached by Edwin and Walker,[46] who suggested using etomidate only in "hemodynamically unstable patients who cannot tolerate an alternative induction agent despite the administration of fluids or vasoactive agents."

Midazolam. Midazolam is often used for procedural sedation because of its rapid onset and its predictable amnestic properties. At our hospital, it is used more commonly by providers who are credentialed by the hospital to provide moderate procedural sedation but not general anesthesia; therefore, it is used frequently in endoscopy and radiology suites and sometimes in the ED. It is an enticing choice particularly in the setting of a septic patient who would not be expected to tolerate the hypotension associated with propofol and for whom one may worry about adrenal insufficiency with the use of etomidate. Choi et al[48] reported a significant decrease in blood pressure more frequently in subjects receiving 2–4 mg midazolam (all doses in this article refer to intravenous administration) for anesthetic induction compared with patients receiving 0.2–0.3 mg/kg etomidate. Tekwani et al[48] compared the use of

etomidate and midazolam in 122 subjects with suspected sepsis and reported no significant difference in hospital or ICU stay or in hospital mortality that could be attributed to the choice of induction medication.

Propofol. Propofol is commonly used for the induction of general anesthesia and for sedation in critically ill, mechanically ventilated patients. Propofol consistently provides good intubating conditions quickly after its administration, and because it may be subsequently administered as a continuous infusion to achieve sedation, it is a logical choice. Hypotension with administration of propofol is its major disadvantage, making it of variable utility for emergency intubation. A meta-analysis of propofol use in the ED reported that in addition to rapidly providing adequate intubating conditions and causing frequent hypotension, subjects receiving propofol frequently became apneic (23% of propofol subjects, 28% of thiopental subjects, and only 7% of etomidate subjects), which should give clinicians pause if they are not confident that they will be able to provide successful positive-pressure ventilation for the patient.[49]

Other Agents. Ketamine and dexmedetomidine are two other commonly used medications for induction and maintenance of both anesthesia and sedation. Ketamine has been shown to be as efficacious as etomidate for RSI, with a similar lack of deleterious effect on hemodynamics.[50,51] Dexmedetomidine has not been investigated specifically for use in RSI, but it has been demonstrated to be effective in facilitating awake fiberoptic intubations.[52] Under circumstances in which there is minimal concern about the possible side effects of bradycardia and hypotension with this α_2-agonist, it may be a good choice of induction agent.

Neuromuscular Blocking Agents

Avoidance of Neuromuscular Blockade. It has been passed down as a truism in bedside teaching ("A patient barely breathing is better than one who is not.") that one should not administer paralytics to a patient to be intubated unless one is certain that positive-pressure ventilation and airway management will be successful. Bozeman et al[53] evaluated intubating conditions with the use of etomidate alone versus RSI (including the use of neuromuscular blocking agents). They reported "good" or "acceptable" intubating conditions in 79% of RSI patients but only in 13% of patients receiving etomidate only, suggesting that avoiding neuromuscular blockade may actually decrease the likelihood of success. Li et al[54] undertook a similarly themed study and compared complications in subjects with RSI versus sedation alone. They reported an increased frequency and severity of complications in cases in which neuromuscular blockage was not used. Aspiration of gastric contents occurred in 15% of non-paralyzed patients, airway trauma in 28%, and death in 3%. None of these complications were observed in the RSI group.

Succinylcholine Versus Rocuronium. Succinylcholine is the neuromuscular blocking agent of choice for RSI because of its rapid onset and short duration of action. There are circumstances in which the use of succinylcholine may be ill advised however, such as in patients who are hyperkalemic, inasmuch as succinylcholine use will produce a transient increase in serum potassium concentration. While the increase in potassium concentration is usually moderate and well tolerated, patients who have been immobile for prolonged periods or who have suffered acute burns have an increase in extrajunctional acetylcholine receptor number and may have exaggerated and life-threatening potassium release as a consequence. Succinylcholine may also trigger an episode of malignant hyperthermia in susceptible patients. Rocuronium is an attractive alternative in such cases. Rocuronium has a similar onset of action as succinylcholine when given in larger doses (1.2 mg/kg as opposed to 0.6 mg/kg). However, its duration of action is significantly longer that that of succinylcholine.[55]

In countries where its use is approved, sugammadex can be used to shorten the duration of rocuronium and further increase the safety and utility of rocuronium for RSI.[56,57] Multiple studies have examined whether rocuronium provides equally favorable intubating conditions as succinylcholine, typically measured by first-attempt success. Patanwala et al[58] concluded that succinylcholine and rocuronium were equivalent, both with 72% first-attempt success rates, when using median doses of 1.65 mg/kg succinylcholine and 1.19 mg/kg rocuronium. Perry et al[59] performed a meta-analysis comparing succinylcholine with high-dose rocuronium and reported no statistical difference in intubating conditions, measured by ease of laryngoscopy, open or moving vocal cords, and response to intubation, based on drug choice alone. They concluded that in the absence of different intubating conditions, succinylcholine was still superior given its preferable time course with shorter duration. In a literature review performed by Mallon et al,[60] the authors concluded that succinylcholine and rocuronium produced similar times to onset of blockade and quality of intubating conditions but that clinicians were more satisfied with the use of succinylcholine. They suggested that, barring contraindication, succinylcholine remain the drug of choice for RSI in the ED. Hiestand et al[3] studied subjects receiving endotracheal intubation by air transportation crews and reported a higher rate of first-attempt success with the use of succinylcholine (OR 1.4 compared with rocuronium). However, they did not report the dose of rocuronium used.

Table 2. Dosing Recommendations for Commonly Used Medications

	Intravenous Dose	Onset and Duration	Side Effects	Monitoring/Comments
Sedatives				
Midazolam (Versed)	0.01–0.03 mg/kg slow IVP q 2–5 min (70 kg = 1–2 mg)	Onset: 2–5 min Duration: 30–60 min	Respiratory depression (especially with opiates), hiccups, bradycardia, apnea, hypotension	• Monitor respiratory and cardiovascular status • Decrease dose by 25–50% when narcotics are given concurrently • No analgesic properties
Lorazepam (Ativan)	0.01–0.04 mg/kg IVP q 5–10 min, dose range 0.5–3 mg	Onset: 10–20 min Duration: 2–4 h	Respiratory depression (especially with opiates), mood changes, rash, chest pain	• Monitor respiratory and cardiovascular status • Use caution in elderly; decrease dose by 50%; expect prolonged wake-up time • No analgesic properties
Etomidate (Amidate)	0.1–0.2 mg/kg IV over 30–60 s, redose at 0.05 mg/kg q 3–5 min as needed	Onset: 10–30 s Duration: 5–15 min	Hypotension, pain at injection site, nausea and vomiting, adrenal insufficiency	• *Deep sedation criteria ONLY* • Monitor respiratory and cardiovascular status • No analgesic properties
Ketamine (Ketalar)	0.5–2 mg/kg IVP over 1 min	Onset: 20–40 s Duration: 30–120 min	Emergence reactions, hypertension, tachycardia, hyperglycemia, muscle hyperactivity, respiratory depression (risk increased when given with other agents)	• *Deep sedation criteria ONLY* • Monitor respiratory function, continuous cardiac monitoring, neurologic function • Emergence reactions may require low-dose benzodiazepine (eg, midazolam, lorazepam) • Mixed sedative/analgesic
Methohexital (Brevital)	0.75–1 mg/kg IVP over 2 min, redose at 0.5 mg/kg q 2–5 min as needed	Onset: 5–20 s Duration: 10–30 min	Respiratory depression, hypotension, pain at injection site, thrombophlebitis	• *Deep sedation criteria ONLY* • Monitor vital signs, level of consciousness • Drug of choice in electrophysiology lab • Limited analgesic properties
Propofol (Diprivan)	0.25–1 mg/kg IVP over 30–60 s, followed by 0.25–0.5 mg/kg q 3–5 min as needed	Onset: 10–30 s Duration: 5–15 min	Hypotension, tachycardia, respiratory depression	• *Deep sedation criteria ONLY* • Monitor respiratory and cardiac monitoring • No analgesic properties
Analgesics				
Fentanyl (Sublimaze)	1–2 μg/kg IVP over 30–60 s q 5–10 min	Onset: 2–5 min Duration: 30–60 min	Respiratory depression (lasting longer than analgesia), truncal rigidity, nausea, vomiting	• Monitor respiratory and cardiovascular status • Respiratory depression risk increased with concomitant sedation
Meperidine (Demerol)	10–30 mg IVP q 5–15 min	Onset: 10–15 min Duration: 2–4 h	Hypotension, seizures, weakness, dizziness, nausea, itching, vomiting, constipation, dysphoric reactions alone or in combination with diazepam	• Monitor respiratory and cardiovascular status • Repeated doses not recommended; avoided in patients with renal dysfunction or elderly patients
Morphine sulfate	1–4 mg IVP q 5–15 min	Onset: 5–10 min Duration: 2–4 h	Dose-dependent orthostatic hypotension, nausea, itching, constipation, respiratory, depression, painful injection	• Monitor respiratory and cardiovascular status • Effects may be prolonged in patients with renal dysfunction
Reversal agents				
Flumazenil (Romazicon, benzodiazepine reversal)	0.2 mg IVP q 1 min up to max dose of 1 mg	Onset: 1–2 min Duration: 1–4 h	Seizures, anxiety, agitation, sweating, headache, flushing, vertigo, dysrhythmias	• Monitor respiratory, cardiovascular, and mental status • Seizure precautions in patients with large dose/chronic benzodiazepine use

(continued)

Table 2. Continued

	Intravenous Dose	Onset and Duration	Side Effects	Monitoring/Comments
Naloxone (Narcan, opiate reversal)	0.04–0.4 mg IVP q 5–10 min up to max dose of 2 mg	Onset: 1–3 min Duration: 30–60 min	Agitation, sweating, tachycardia, flash pulmonary edema, seizures, nausea and vomiting	• Monitor respiratory and cardiovascular status • Start low and titrate as needed
Sugammadex (Bridion, reversal of aminosteroid neuromuscular blockers)	2–4 mg/kg IVP	Onset: 2–3 min Duration: up to 24 h	Possible interference with coagulation pathways, concerns over hypersensitive reactions, bradycardia	• Reversal of neuromuscular blockade by rocuronium or vecuronium • Not FDA-approved in United States • Not evaluated for use in critically ill patients • Not recommended for patients with renal impairment • Dose according to actual body weight
Neuromuscular blocking agents (intubating doses)				
Succinylcholine (Anectine)	1–1.5 mg/kg IVP	Onset: 1 min Duration: 5–20 min	Vagally mediated bradycardia, salivation	• Suitable for rapid sequence intubation • Hydrolysis by plasma cholinesterase • Use with caution in critical illness • Hyperkalemia with burns, severe immobility • Contraindicated in malignant hyperthermia • Calculate dose on ideal body weight
Rocuronium (Zemuron)	0.6–1.2 mg/kg IVP	Onset: 1–1.5 min Duration: 40–150 min	Occasional tachycardia	• High dose (1.2 mg/kg) suitable for rapid sequence intubation as alternative to succinylcholine • Excreted primarily by the liver
Vecuronium (Norcuron)	0.1–0.12 mg/kg IVP	Onset: 2–3 min Duration: 25–65 min	Minimal cardiovascular effects	• Prolonged duration of action in hepatobiliary disease • Not recommended for rapid sequence intubation because of onset
Cisatracurium (Nimbex)	0.15–0.2 mg/kg IVP	Onset: 2–2.5 min Duration: 50–60 min	Hypersensitivity/anaphylactic reactions	• Metabolized via Hofmann elimination to inactive metabolites • Not recommended for rapid sequence intubation because of onset

From Reference 64, with permission.
IVP = intravenous push
IV = intravenous
q = every

Recommendations. Excluding patients with active cardiac arrest who are unlikely to respond physiologically to endotracheal intubation, it is clear that the use of medication facilitates the success of emergency endotracheal intubation. When choosing a sedation agent, it would be most appropriate to do so in the clinical context of the patient. A patient with severe hypotension would probably be best managed with etomidate, whereas a hemodynamically stable patient with suspected sepsis may be induced with agents other than etomidate. Regardless of the drug used, it is reasonable practice to anticipate hypotension and to have intravenous fluids and vasopressor agents, such as phenylephrine or ephedrine, immediately available when administering sedatives or anesthetics in anticipation of endotracheal intubation. Dosing of these sedative/hypnotics, opiates, and neuromuscular blockers is generally clear in healthy patients (Table 2). Anecdotally, critically ill patients may be adequately anesthetized by far lower induction doses than healthier patients; it is not uncommon to achieve general anesthesia in critically ill patients with 0.5 mg/kg propofol or 0.1 mg/kg etomidate.

Regarding the use of neuromuscular blocking agents, current evidence supports their use to facilitate emergency endotracheal intubation. When choosing between rocuronium and succinylcholine, it appears that succinylcholine remains the preferred drug if there is no concern for significant hyperkalemia or risk for malignant hyperthermia.

Multiple Attempts at Intubation

Performing emergency endotracheal intubation necessarily means doing so under less than ideal conditions. Rates of first-time success will be lower compared with endotracheal intubation performed under controlled con-

ditions in the operating room. The consequences of this lower success rate have been evaluated in multiple studies. Mort[61] retrospectively examined 2,833 critically ill subjects requiring emergency intubation and reported that with more than 2 attempts at intubation, there was an increased rate of hypoxia (70 vs 12%), esophageal intubation (51 vs 5%), vomiting (22 vs 2%), aspiration (13 vs 1%), bradycardia (21 vs 2%), and cardiac arrest (11 vs 1%). Hasegawa et al[62] prospectively studied 2,616 subjects receiving emergency endotracheal intubation in the ED. Eleven percent required at least 3 attempts at intubation. Compared with those who were intubated in one or two attempts, subjects requiring multiple attempts experienced higher rates of adverse events (35 vs 9%, with an OR of 4.5). The adverse events they examined were esophageal intubation with delayed recognition, hypotension, regurgitation, hypoxia, dysrhythmia and cardiac arrest, dental or lip trauma, endobronchial intubation, and airway trauma. Sakles et al[63] examined 1,828 emergent intubations in the ED. The adverse events they evaluated were accidental extubation, aspiration, cardiac arrest, cuff leakage, dental trauma, arrhythmia, esophageal intubation, hypotension, laryngospasm, endobronchial intubation, desaturation, and pneumothorax. Subjects successfully intubated on the first attempt had only a 14% chance of developing one of these complications, whereas 47% of subjects requiring two or more attempts experienced an adverse event.

Conclusions

It is clear that with additional attempts at emergency intubation, more complications occur. Accordingly, it is best to "do it right the first time." Do whatever is possible to maximize the chance of first-attempt success. This may require using a different device or technique for ETT placement, choosing a more experienced provider to perform the intubation, or using medications to achieve sedation and neuromuscular blockage. Obviously, many health care providers need to learn to perform emergency endotracheal intubation, but the preponderance of evidence suggests that emergency situations are not the setting in which they should initially learn their intubation skills.

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Discussion

Hess: What do you think the emergency medicine folks would say about your first bullet point, to use bag-mask ventilation [BMV] rather than endotracheal intubation in the field?

Hurford: They'd probably disagree, but I don't think they have reason to. I think once someone gets to the hospital, they've undergone arrest for some time. But think about it for a little bit, what are the physiologic changes that occur? First of all, there's no cardiac output. If your heart isn't beating, it's pointless to ventilate the patient; you can have all the O_2 in your lungs that you want, but it's not going anywhere. So there's no need, until circulation is re-established with good chest compressions, to ventilate the patient at all. Second, if you are going to provide any sort of positive-pressure ventilation, what's going to be the effect of that? You're going to decrease venous return and decrease the efficacy of the chest compressions in general unless you're coordinating positive pressure with the compressions by using an impedance device or an automated device. The third issue is the time that's required for laryngoscopy and intubation. And that's time during which attention is taken away from restoring circulation of the patient—no one's giving CPR [cardiopulmonary resuscitation], everybody's standing around waiting for the tube to go in, chest compressions are interrupted probably for an overly long period of time, and defibrillation is delayed, which is the one effective thing we can do to restore circulation. So, for those reasons, there's a lot of good physiological rationale to delay intubation until later. You can get the tube in after a return to spontaneous circulation.

Berkow: I totally agree; I did the extensive literature search comparing BMV versus an LMA [laryngeal mask airway] or ETT [endotracheal tube] for the last set of CPR guidelines[1] that came out in 2010. The literature is clear that an ETT isn't superior to BMV; you get similar V_T [tidal volume] and similar results. And we do know that delaying chest compressions to manage the airway is bad. We also know that hyperventilation is bad as well. So there's a lot of good evidence, including evidence showing there's no improvement in outcomes between chest compression alone versus chest compressions with ventilation. I totally agree with your comments.

Durbin: Same issue; there are outcome data which suggest that if you inadvertently hyperventilate in the field, which is more likely with an ETT, the outcome in head trauma is much worse.[2] If you don't intubate, you end up with more patients in the natural range because it's more difficult to hyperventilate them. Even when rescuers were given an end-tidal CO_2 monitor, P_{aCO_2} on arrival was still frequently far outside the normal range, and this correlated with a worse outcome.[3] I think we don't know all the reasons yet, but it seems that the cerebral circulation continues to respond to CO_2, even in trauma patients. Hyperventilation is bad, and intubation seems to increase the incidence of it.

Ramachandran: Let me play devil's advocate. How about if there's a huge amount of indication bias to this sort of assumption that ETTs induce injury through the mechanisms you described? In other words, the people who are in prehospital areas, the first thing people do often is slap on a defib if it's available. Because, like you said, it's the one intervention that an advanced practitioner of resuscitation would bring to the patient. And that would be in line with the new AHA [American Heart Association] recommendations.[1] I actually find it interesting, I did the analysis of the AHA NRCPR [National Registry of Cardiopulmonary Resuscitation] database, and I could not get a propensity match between those who did not get intubated to those who did for in-hospital arrests. And I think the reason is because people who don't get intubated just have much less severe disease, much less severe stage of health when they have cardiac arrest compared to those who do get intubated. So there's quite a lot of indication bias that goes into our assumption for us to say it's a therapeutic (negative) effect of intubation. But there are other theories with lend themselves to your con-

clusions, one of which is that if you have an open glottis, the intrathoracic pressure that you generate during CPR may to be dissipated out this way compared with a partially closed glottis. I also find it interesting that LMAs have a similar outcome to ETTs because they're supraglottic.

Berkow: I have a comment about sedation and the use of medications, including etomidate. I think the challenge is in these emergent unstable patients, even if they have adequate blood pressure, once you intubate them and you take away their drive to breathe, they all get hypotensive. So I always worry about whatever medications I'm going to give to make a relatively stable patient unstable when you take away that last catecholamine surge. I agree with you; I'm often less worried about the effects of adrenal insufficiency when choosing to give etomidate versus the extreme hypotension that may be much harder to treat if I give propofol. I think you always have to consider what your drugs are going to do to your unstable patient when you take away all those catecholamines.

Hurford: Right. Simply anticipating the hypotension and having the volume infusing already or ready to go. Phenylephrine or ephedrine can be in line to give with or before you give the sedative drug because you know that hypotension will occur in the vast majority of patients.

Berkow: I have another question for you. If sugammadex ever reaches the United States, do you think that's going to potentially change our choice of succinylcholine versus rocuronium?

Hurford: Depends on the price whether it really will become a useful drug in clinical practice or not. If it's going to cost $100 to reverse rocuronium, I think we'll still use succinylcholine regardless of the side effects of sugammadex.

Durbin: We go through times where we don't even have succinylcholine. I don't know about your drug availability issues, but ours are severe. What is available on Monday may be different on Tuesday. So I'll take anything that results in more rational choices. I think even an expensive sugammadex is a good thing to have around, even if you never use it. Succinylcholine is a fabulous drug under most circumstances, but if you don't have it, you aren't going to use it. The other choices are less ideal. Sugammadex would be a good thing to have around.

Blank: As a follow-up to Dr Berkow's comment, etomidate is often favored in patients who are hemodynamically unstable even if they haven't suffered from an arrest. There may be reasonable bias for etomidate in patients with poor cardiac function since, unlike most other induction agents, it does not significantly depress systolic function. My question relates to the CORTICUS [Corticosteroid Therapy of Septic Shock] study[4] because I don't recall; how well did they control for the fact that there's likely a bias in terms of which patients get etomidate—those that are more likely (or at least thought to be more likely) to be unstable?

Hurford: They didn't. Often you'll say if a patient received etomidate, they received it because they were sicker, at least at the time of intubation. I think that's hard to tease out of the study. The second point to make is that etomidate seems to be a drug that one dose fits all because you're not as worried about hypotension, where with the other drugs we can administer, there is an exquisite dose-response relationship in patients who are sick or hypotensive. Smaller doses, as you know, can be very effective at providing an adequate level of anesthesia. 20-40 mg of propofol in those patients can be a wonderful induction dose rather than 100-200 mg.

Durbin: I agree with you: it isn't the drug we choose, it's the amount we give of it. Even etomidate drops blood pressure in the sickest patients in low doses. If we're trying to specify what can somebody in the field who's not a physician, not an anesthesiologist, use, perhaps etomidate is the better choice. There will be less instability with etomidate than with any of the others except perhaps midazolam, which doesn't put the patient to sleep. With midazolam, most patients won't remember much of what happens after it is given. If the patient is so ill that you're worried about drug choice, small doses of midazolam are probably appropriate. A live patient who remembers a little bit is better than a dead one who doesn't.

Hurford: What is the experience of the group with ketamine?

Ramachandran: I used ketamine a lot in India when I first trained, and it's a phenomenal drug. I haven't really seen the other side of it, which is severe hypotension with induction doses. I haven't used it as much in this country, so I don't know if it's a genetic response difference between what we saw in India and what I see here. I think it is a phenomenally safe drug, even for trauma resuscitation.

Blank: We also use a fair amount of ketamine in the cardiac ORs [operating rooms] with patients who are unstable presenting with tamponade, for example. It is important to keep in mind that ketamine is also a myocardial depressant. The sympathetic stimulation it provides can compensate for the depression in patients who are not already maximally sympathetically stimulated. We do occasionally see that property unmasked in patients who are in extremis from a cardiovascular standpoint.

Hurford: Our military colleagues now are using it pretty much as their drug of choice for intubation. But these

are young, otherwise healthy soldiers without myocardial depression.

Ramachandran: One additional comment. I just reviewed our department's QA [quality assurance] data on sudden deaths in severe hypotension with pulmonary hypertensives, and we actually found those who got ketamine had fewer instances. So I don't know if that's again a physician choosing appropriately as to which patient gets a drug. But even patients with severe pulmonary hypertension did not have an increase in events compared to those who got ketamine.

Durbin: I would like to comment on ketamine dosing. One-quarter mg/kg is enough to stun a child and allow you to do a lumbar puncture without pain even in a 14-year-old. One mg/kg is a moderate anesthetic induction dose. Four mg/kg is an IM [intramuscular] anesthetic induction dose. It depends on the dose whether you're going to need to deal with the side effects or the primary effects of the drug. Ketamine has potent analgesic effects as well; this is demonstrated by burn patients who are repeatedly undergoing painful debridements. A dose of one-quarter mg/kg can be a safe anesthetic dose in an unstable, critically ill person.

Berkow: As far as attending supervision in emergent intubations, I do think it makes a difference. At our institution several years ago, we made it a rule that you must have an attending anesthesiologist present at all intubations outside the OR. And we saw a significant decrease in unplanned emergent surgical airways.

Hurford: Do you require anesthesiologists in the ER [emergency room] or SICU [surgical ICU]?

Berkow: At our institution, we go to all intubations in all the ICUs. And in the ER, we alternate with the emergency department for trauma management. Similarly, the emergency department requires an attending emergency medicine physician be present for all intubations.

Hurford: So, do you think it's having the trained attending or a particular specialty present?

Berkow: There's some argument as to whether it's the actual attending or just the fact that you have a second skilled provider that makes a difference. And there's literature on both sides. We took it a step farther about 5 years ago and created a multidisciplinary airway team made up of trauma surgeons, otolaryngologists, emergency medicine physicians, and anesthesiologists. The team can be activated for difficult airways, and we've found that this multidisciplinary approach has even further improved our adverse outcomes outside the OR. I think it's expertise, and I think the more expertise you bring for these challenging intubations, the fewer complications you get. The challenge is getting everybody to play well together in the sandbox and remove the egos of 'I'm going to do it.' That's the biggest challenge, I think. We've managed to over time get our team to work well together.

Napolitano: What about the middle of the night?

Berkow: Our team is 24/7.

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