Death and Other Complications of Emergency Airway Management in Critically Ill Adults

A Prospective Investigation of 297 Tracheal Intubations

David E. Schwartz, M.D.,* Michael A. Matthay, M.D.,† Neal H. Cohen, M.D.‡

Background: Hospitalized patients outside of the operating room frequently require emergency airway management. This study investigates complications of emergency airway management in critically ill adults, including: (1) the incidence of difficult and failed intubation; (2) the frequency of esophageal intubation; (3) the incidence of pneumothorax and pulmonary aspiration; (4) the hemodynamic consequences of emergent intubation, including death, during and immediately following intubation; and (5) the relationship, if any, between the occurrence of complications and supervision of the intubation by an attending physician.

Methods: Data were collected on consecutive tracheal intubations carried out by the intensive care unit team over a 10-month period. Non-anesthesia residents were supervised by anesthesia residents, critical care attending physicians, or anesthesia attending physicians.

Results: Two hundred ninety-seven consecutive intubations were carried out in 238 adult patients. Translaryngeal tracheal intubation was accomplished in all patients. Intubation was difficult in 8% of cases (requiring more than two attempts at laryngoscopy by a physician skilled in airway management). Esophageal intubation occurred in 25% (8%) of the attempts but all were recognized before any adverse sequelae resulted. New infiltrates suggestive of pulmonary aspiration were present on chest radiograph after 4% of intubations. Seven patients (3%) died during or within 30 min of the procedure. Five of the seven patients had systemic hypotension (systolic blood pressure ≤ 90 mmHg), and four of the five were receiving vasopressors to support systolic blood pressure. Patients with systolic hypotension were more likely to die after intubation than were normotensive patients (P < 0.001). There was no relationship between supervision by an attending physician and the occurrence of complications.

Conclusions: In critically ill patients, emergency tracheal intubation is associated with a significant frequency of major complications. In this study, complications were not increased when intubations were accomplished without the supervision of an attending physician as long as the intubation was carried out or supervised by an individual skilled in airway management. Mortality associated with emergent tracheal intubation is highest in patients who are hemodynamically unstable and receiving vasopressor therapy before intubation. (Key words: Anesthetic techniques: tracheal intubation. Emergency airway management: aspiration; endobronchial intubation; pneumothorax. Emergency intubation, airway management: complications.)

MAINTENANCE of a patent airway is essential to the management of the critically ill patient.1,2 In the intensive care unit, airway management usually requires translaryngeal intubation of the trachea.3 Complications associated with this procedure range from local trauma of the airway as a result of the intubation procedure to death caused by unrecognized misplacement or malpositioning of the endotracheal tube.4,5

Airway management in critically ill patients differs significantly from tracheal intubation carried out for a routine surgical procedure. In the operating room, most intubations are done under elective, controlled conditions by skilled physicians formally trained in airway management; the complication rate is low.6,7 In contrast, airway management of the critically ill patient often requires emergent intubation in a patient suffering from respiratory failure, shock, or cardiopulmonary arrest.8 The procedure often is carried out by practitioners who do not routinely perform tracheal intubations under elective circumstances or, in academic medical centers, by physicians-in-training under less than ideal conditions. For patients in whom the trachea

* Assistant Professor of Anesthesia and Medicine.
† Professor of Medicine and Anesthesia.
‡ Professor of Anesthesia and Medicine.

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Address correspondence to Dr. Schwartz: Division of Critical Care Medicine, University of California, San Francisco, San Francisco, California 94143-0624.

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is intubated outside of the intensive care unit, little time may be available for evaluation, examination, and preparation of the patient.

Only two large studies have reported complication rates for intubation in critically ill adult patients; neither study was specifically designed for this purpose. In these studies, the complications of intubation included prolonged intubation attempt, seizures, cardiac arrest, right mainstem intubation, pneumothorax, and pulmonary aspiration of gastric contents.

Because neither of the prior studies was designed to prospectively evaluate translaryngeal intubation of the trachea in the critically ill adult, we carried out a prospective study of the complications of tracheal intubation in this group of patients. We published a report documenting the incidence of right mainstem intubation in this patient population. The questions we sought to answer for this study include: (1) What is the frequency of difficult and failed tracheal intubation in critically ill adults? (2) After emergent intubation in the critically ill patient, what is the incidence of esophageal intubation, pneumothorax, and pulmonary aspiration? (3) What is the mortality associated with airway management in this group of patients? 4) What, if any, is the relationship between complications and whether an attending physician supervised the procedure?

Methods

Over a 10-month period, all emergent tracheal intubations were studied prospectively in adult patients at Moffitt/Long Hospitals of the University of California, San Francisco. The Committee on Human Research approved the study and waived the requirement for informed consent.

The physicians of the critical care medicine service are responsible for all emergent intubations in hospitalized adults outside of the operating room. The intubations were carried out in a 16-bed medical-surgical intensive care unit (ICU), a 14-bed cardiac care unit, an 8-bed neurology-neurosurgery ICU, an 8-bed cardiothoracic-vascular surgery ICU, the acute care hospital floors, any other patient care location outside of the operating room (e.g., radiology department, cardiac catheterization laboratory), as well as during cardiopulmonary resuscitation. Our institution does not routinely care for victims of trauma or burns. These patients therefore, are not represented in this study.

The critical care medicine service consists of residents from the departments of anesthesia, medicine, and surgery who are assigned to the intensive care unit for 1–2 months, as well as fellows in pulmonary medicine and critical care medicine. The residents and fellows are supervised by six critical care medicine attending physicians who have been formally trained in airway management and critical care medicine. The attending physicians have specialized training in anesthesiology (one), internal medicine and anesthesiology (three), and pulmonary and critical care medicine (two).

During the intensive care unit rotation, formal training in airway management of the critically ill patient is provided to all resident and fellow physicians. This educational program emphasizes the importance of airway evaluation, preoxygenation, and ventilation via mask with 100% O2, techniques to prevent aspiration, routine techniques for oral and nasal intubation, and the management of the difficult airway. Equipment and techniques for managing the difficult airway (laryngeal masks, intubating stylettes, fiberoptic bronchoscopy, transtracheal ventilation devices) are reviewed and readily available. Although a commercially available cricothyroidotomy kit is available, the performance of this procedure by a surgeon is encouraged. The pharmacology, hemodynamic and adverse effects of sedative/hypnotic medications, opioids, and muscle relaxants are reviewed. Residents are instructed to use cricoid pressure to prevent pulmonary aspiration of gastric and oropharyngeal contents and to limit attempts at laryngoscopy to no more than 45 s. Ventilation by bag and mask with 100% O2 is to be provided to patients before and between attempts at laryngoscopy.

For the purposes of this study, we considered an individual to be skilled in airway management if they had completed at least 6 months of an anesthesia residency or was a critical care medicine attending physician. All intubations done by physicians who have not had at least 6 months of anesthesia resident training are supervised by an anesthesia resident or a critical care medicine or anesthesia attending physician.

After intubation, adequate positioning of the endotracheal tube was confirmed by the intubating physician and the supervisor using clinical criteria, including the auscultation of bilateral breath sounds over the apices of the lungs, the lack of breath sounds over the epigastrium, observation of symmetrical chest expansion, and palpation of the cuff of the endotracheal tube in the
suprasternal notch. The detection of carbon dioxide in the exhaled gas was not routinely used to assess the intratracheal location of the endotracheal tube. Immediately after intubation, a chest radiograph was obtained with the patient's head in neutral position to confirm adequate endotracheal tube position and to document aspiration or pneumothorax. Chest radiographs were interpreted by attending radiologists.

The data collected for each intubation are listed in Table 1. All data were obtained by the intubating physician or the supervisor and verified by the investigators.

All intubations carried out by the critical care medicine physician staff are initially attempted by resident physicians or fellows. We chose to define a difficult tracheal intubation as one that required three or more attempts at laryngoscopy to place the endotracheal tube into the trachea by an individual skilled at airway management. If a nonskilled individual could not intubate the patient's trachea with two attempts at laryngoscopy, intubation was attempted by the skilled supervisor. Only if the supervisor required more than two attempts at laryngoscopy to place the endotracheal tube within the trachea was the intubation considered difficult.

To assess the hemodynamic impact of tracheal intubation, data regarding the route of intubation, medications used to facilitate the procedure, and the number of deaths were categorized according to the systolic blood pressure of the patient immediately before intubation. Group 1 consists of intubations carried out in patients without an obtainable blood pressure. Group 2 includes patients with systolic blood pressure of ≤90 mmHg, and in group 3, the systolic blood pressure was >90 mmHg. For the purposes of this study, a death during or within 30 min of an intubation was considered to be associated with the procedure.

For statistical analysis, chi-square was used to test for significant differences in the complications of intubations. Statistical significance was considered a P value less than 0.05.

**Results**

**Demographics and Clinical Details.** Two-hundred ninety-seven consecutive intubations were carried out in 238 adults, 185 intubations in men and 112 in women. In each of 189 patients, the trachea was intubated once, in 40 patients twice, in 8 patients three times, and in 1 patient four times. The patients ranged in age from 20 to 89 yr; the average age was 45 yr.

**Indication for Intubation.** The patients primary diagnoses at the time of tracheal intubation are presented in Table 2. The clinical indication for tracheal intubation included respiratory failure (50%), airway protection (17%), and cardiac and/or respiratory arrest (10%; fig. 1).

**Location of Intubation.** Most intubations were carried out in a critical care unit. Fifty-two percent of

<table>
<thead>
<tr>
<th>Table 1. Data Collected for Each Patient Intubation</th>
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<tbody>
<tr>
<td><strong>Demographics</strong></td>
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<tr>
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<td>Age</td>
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<tr>
<td>Sex</td>
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<tbody>
<tr>
<td>Diagnosis</td>
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<tr>
<td>Cardiac disease</td>
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<tr>
<td>Hematologic/oncologic malignancy</td>
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<tr>
<td>Solid organ transplant</td>
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<tr>
<td>Neurologic disease</td>
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<tr>
<td>Neurologic surgery</td>
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<tr>
<td>COPD/asthma</td>
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<td>Liver failure</td>
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<tr>
<td>Vascular surgery</td>
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<td>Cardiothoracic surgery</td>
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<td>Bone marrow transplant</td>
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<td>Gastrointestinal hemorrhage</td>
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<td>Pulmonary emboli</td>
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<tr>
<td>Miscellaneous*</td>
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<td>Total</td>
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COPD = chronic obstructive pulmonary disease.

* Miscellaneous diagnoses include renal failure, vocal cord paralysis, drug overdose, alveolar proteinosis, thrombotic thrombocytopenic purpura, trauma, scleroderma, pancreatitis, necrotizing fasciitis, mesenteric thrombosis, lethal midline granuloma, hemochromatosis, hemolytic uremic syndrome, and diabetes.

† There were 297 intubations in 238 patients.
SCHWARTZ, MATTHAY, AND COHEN

NUMBER OF INTUBATIONS

Fig. 1. The number of intubations according to each clinical indication. Respiratory failure includes patients intubated for hypoxemia and/or hypercarbia. Endotracheal tube (ETT) change was carried out because of ETT malfunction or to change the location of the ETT (i.e., oral to nasal). Procedure refers to intubation for procedures such as gastrointestinal endoscopy and bronchoscopy. Intubations for cardiac and respiratory (resp) arrest are combined.

Intubations were done in the medical-surgical ICU, 26% in one of the other critical care units, 15% on hospital wards, 3% in the emergency department, and 3% in other locations (radiology department, cardiac catheterization laboratory, and the postanesthesia care unit). The complications of intubation did not differ by location or time of day of the procedure.

Personnel Involved in Intubation. Anesthesia residents carried out 31% of intubations; nonanesthesia residents, 32%; and critical care fellows, 30%. Attending physicians performed 7% of the intubations. Forty-six percent of the intubations were supervised by an attending physician; the other 54% were carried out or supervised by an anesthesia resident.

Medications Administered for Tracheal Intubation. Muscle relaxants were used to facilitate 80% of all intubations; succinylcholine was used for 57% (table 3). The use of sedative/hypnotics and opioids for intubation are shown in table 4.

Route and Difficulty of Intubation. All tracheal intubations were successfully achieved by the oral or nasal route; no patient required surgical intervention for airway control. In 274 of 297 (92%) intubations, the endotracheal tube was placed orally; the remaining 23 (8%) were inserted nasally. Direct laryngoscopy was used in 268 (90%) of the intubations (including 5 nasal intubations). Of the 29 intubations in which direct laryngoscopy was not used, 10 oral endotracheal tubes were replaced using an intubating stylet, and 1 oral intubation was accomplished with a fiberoptic bronchoscope. Eighteen were nasal intubations. Three of the nasal intubations were performed using a fiberoptic bronchoscope; the remaining 15 were performed "blindly." However, five attempts at blind nasal intubation were unsuccessful; in these patients, the tracheas were intubated under direct vision.

Of the 297 intubations, 89% were accomplished on the first or second attempt (fig. 2). Thirty-two procedures (11%) required more than two attempts at intubation. Of these 32 intubations, 24 (8%) met criteria for a difficult intubation; the other 8 were initially attempted by nonskilled personnel and were then easily accomplished by an individual meeting our definition of competence in airway management. Of the 24 intubations that were difficult, 13 required four or more attempts at laryngoscopy and two of these required ten attempts each before the trachea was intubated.

Multiple attempts at intubation were not associated with adverse outcomes, such as seizures or cardiac arrest. In fact, one patient in whom intubation was difficult was successfully resuscitated after a cardiorespiratory arrest while receiving ventilation via mask with oxygen before successful tracheal intubation.

Esophageal Intubation. During 25 of the 297 (8%) intubation procedures, the tip of the endotracheal tube was initially placed into the esophagus. Only 10 of 25 (40%) procedures that resulted in esophageal intubation met criteria for difficult intubation. During 22 of the 25 intubations, the esophagus was intubated only once before tracheal intubation was accomplished. In the remaining three, the esophagus was intubated a total of 13 times before successful completion of tracheal intubation. Thus, there were 35 esophageal intubations among the 25 procedures.

Of the 35 esophageal intubations, 32 were recognized by clinical criteria, which included auscultation of breath sounds and gastric distention. Three esophageal intubations were not recognized until there was a decrease in the oxyhemoglobin saturation as measured by pulse oximetry. No patient suffered hemodynamic instability or other adverse event that could be attributed to esophageal intubation. There was no relationship between the occurrence of esophageal intubation and whether an attending physician supervised the intubation (P = 0.80).

Pneumothorax and New Infiltrates/Aspiration on Chest Radiographs. Chest radiographs to deter-
mine endotracheal tube position were obtained in 272 of the 297 intubations. In 20 cases, the patient expired before a radiograph was obtained; in 4, the tracheas were briefly intubated for a procedure and then exubated; and in 1, the position of the endotracheal tube was confirmed by bronchoscopy.12

In two patients (1%), a pneumothorax was present on the chest radiograph taken immediately after intubation. No cause other than airway instrumentation and positive pressure ventilation could explain the pneumothorax. In one patient, laryngoscopy was attempted only once; whereas, in the second patient, three laryngoscopies were performed before successful intubation.

In 24 cases, a new or unexpected infiltrate was present on the chest radiograph obtained immediately after intubation. In 12 cases, the patient had a history of aspiration before the need for intubation. Thus, 12 patients (4%) had an unexplained infiltrate that probably resulted from aspiration during airway management. In each of these patients, the trachea was intubated orally. Seven of the patients were not considered to have a full stomach at the time of intubation. Nine of the 12 patients had cricoid pressure applied during airway management; 3 did not. Intubation was difficult in 3 of the 12 patients, and 2 of these patients had the endotracheal tube initially placed into the esophagus.

There was no statistically significant relationship between whether the intubation was supervised by an attending physician and the detection on chest radiograph of pneumothorax (P = 0.19) or aspiration (P = 0.98).

Mortality. Group 1 consisted of the 27 intubations, which were carried out in patients without a measurable blood pressure; 14 of these patients could not be resuscitated (table 5). In the remaining 270 intubations, there were seven deaths at the time of or within 30 min after intubation (mortality rate of 3%). Five of these seven deaths occurred in group 2 patients (systolic blood pressure ≤ 90 mm Hg), for a mortality rate of 15%. The diagnoses of the five patients that died in this group included ruptured abdominal aortic aneurysm, dissecting aortic aneurysm, variceal hemorrhage, pneumonia, and respiratory failure (one patient, after hip arthroplasty). Four of these five patients had a systolic blood pressure of 60 mm Hg or less at the time of intubation, and four were receiving vasoactive medications (dopamine and/or phenylephrine) for support of systolic blood pressure. Four patients received succinylcholine to facilitate laryngoscopy; the trachea of

### Table 3. Route of Intubation and Muscle Relaxants Used for Intubation

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<tr>
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<td>0</td>
</tr>
<tr>
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<td>34</td>
<td>34</td>
<td>0</td>
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<td>20</td>
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</tr>
<tr>
<td>3</td>
<td>236</td>
<td>213</td>
<td>23</td>
<td>25</td>
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<td>Total</td>
<td>297</td>
<td>274</td>
<td>23</td>
<td>59</td>
<td>170</td>
<td>68</td>
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</table>

* Group 1 did not have an obtainable blood pressure at the time of intubation, group 2 had systolic blood pressure of ≤ 90 mmHg, and group 3 had systolic blood pressure > 80 mmHg.

### Table 4. Sedatives and Opioids Used for Intubation

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of Intubations</th>
<th>No. Without Sedatives/Opioids</th>
<th>Thiopental</th>
<th>Benzodiazepines</th>
<th>Opioids</th>
<th>Ketamine</th>
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<tbody>
<tr>
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<td>3</td>
<td>236</td>
<td>37</td>
<td>171</td>
<td>14</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>297</td>
<td>86</td>
<td>177</td>
<td>16</td>
<td>13</td>
<td>5</td>
</tr>
</tbody>
</table>

The sedatives include thiopental, benzodiazepines, and ketamine. The opioids include fentanyl, morphine, and meperidine. Group 1 did not have an obtainable blood pressure at the time of intubation, group 2 had systolic blood pressure of ≤ 90 mm Hg, and group 3 had systolic blood pressure of > 90 mm Hg.

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the fifth patient was intubated without the use of muscle relaxants. None of these five patients received any sedative/hypnotic agent or opioid. Two of these intubations were supervised by an attending physician and three were supervised and/or performed by an anesthesia resident.

In group 3 (systolic blood pressure > 90 mmHg), two deaths were associated with 236 intubations (mortality of 0.85%). The mortality in group 3 patients was significantly lower than in group 2 patients ($P < 0.001$). A patient with leukemia had a $\text{PaO}_2$ of 112 mmHg $\text{PaCO}_2$ of 90 mmHg and a pH of 6.99 and was given 100 mg sodium thiopental and 100 mg succinylcholine for intubation, which was accomplished easily. Ten minutes later, the patient had ventricular fibrillation and could not be resuscitated. The other patient who died in this group had undergone cadaveric renal transplantation, and the trachea was intubated because of pulmonary edema complicating acute myocardial infarction. He received a single bolus of 300 mg sodium thiopental and 100 mg succinylcholine, and his trachea was easily intubated. Immediately after the administration of these medications, the patient became profoundly hypotensive, arrested, and could not be resuscitated.

When comparing mortality between the patients with systolic hypotension at the time of intubation (group 2) with the normotensive patients (group 3), there was a statistically significant relationship between systolic hypotension and patient death ($P < 0.001$). For all intubations in groups 2 and 3, there was no statistically significant relationship between patient death and whether the intubation was supervised by an attending physician ($P = 0.31$).

**Discussion**

A translaryngeal endotracheal tube is accepted as the airway of choice for most critically ill patients. Tracheal intubation is indicated for protection and maintenance of a patent airway, the provision of mechanical ventilation and oxygen therapy, and pulmonary hygiene. Thus, expert management of the airway is essential in the care of the critically ill patient. The skills required for airway management include the ability to provide adequate ventilation and oxygenation using a resuscitation bag and face mask, as well as competence in multiple approaches for translaryngeal intubation of the trachea.

Only a few studies have evaluated the complications of airway management in critically ill adults. Most of these studies have focused on the complications of the use of an artificial airway; none was designed primarily to evaluate the immediate complications of endotracheal tube placement. Thus, this study is the first prospective examination of the proximate complications of airway management in the critically ill adult.

The occurrence of all major complications of emergency tracheal intubation is summarized graphically in figure 3. The incidence of right mainstem intubation (4%) in this study population is included in this figure, which, as previously reported, was not detected by clinical examination and found only on the chest radiograph obtained immediately after intubation.

**Mortality**

For this study, we defined intubation that was associated with mortality as death that occurred during or

**Table 5. Mortality after Intubation**

<table>
<thead>
<tr>
<th>Group</th>
<th>Preintubation Systolic BP (mmHg)</th>
<th>No. of Intubations</th>
<th>No. of Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>27</td>
<td>14</td>
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<tr>
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<td>3</td>
<td>&gt;90</td>
<td>236</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>297</td>
<td>21</td>
</tr>
</tbody>
</table>

BP = blood pressure.

The mortality in group 2 was 15% versus 0.85% in group 3.

* $P < 0.001$ versus group 3.
COMPLICATIONS OF EMERGENCY INTUBATION

![Graph showing percentage of intubations](image)

Fig. 3. The percentage of intubations in which major complications occurred. For the first two categories (difficult intubation and esophageal intubation), the total number of intubations was 297. The detection of mainstem intubation and aspiration required a chest radiograph. Chest radiographs were obtained in 272 of the 297 intubations. Mortality is calculated based on the 270 intubations carried out for patients with an obtainable blood pressure at the time of the procedure.

within 30 min of the procedure. During 270 intubations in patients with an obtainable systolic blood pressure, seven patients (3%) met this definition of intubation associated mortality.

Of these deaths, five occurred in patients who were hypotensive (systolic blood pressure of ≤90 mmHg); four of the five were receiving vasoactive medications to increase their blood pressure. None of these patients received any sedative/hypnotic agent at the time of intubation, both because of a preexisting decreased level of consciousness and because of concern regarding the detrimental hemodynamic effects of these drugs. The possible causes of death include the institution of positive pressure ventilation with the attendant increase in intrapleural pressure and decrease in venous return to the heart, progression of the underlying disease process, or other unknown factors. Further studies are needed to clarify the cause(s) of death in these patients. However, the presence of systolic hypotension markedly increased the risk of death after intubation in critically ill patients in this study (15% vs. < 1% in the absence of hypotension).

In the normotensive patients, there were two deaths. One patient expired from ventricular arrhythmias which occurred shortly after intubation. In this patient, intubation and positive pressure ventilation were not associated with significant hemodynamic alterations, and we cannot ascribe the arrhythmias to the intubation nor the institution of positive pressure ventilation. The death of the second patient, who had an acute myocardial infarction, was probably due to a large bolus dose of sodium thiopental; the patient immediately became hypotensive, cardiac arrest occurred, and resuscitation was unsuccessful.

This latter death emphasizes that sedative/hypnotic agents in critically ill patients should be administered in small doses titrated carefully to the patient's level of consciousness and hemodynamic responses. The use of a standard anesthetic induction dosage of a sedative hypnotic agent is dangerous in critically ill patients.4,16

**Difficult Intubation**

The literature does not provide a standard definition of the difficult airway.17 The American Society of Anesthesiologists has defined a difficult airway as "the clinical situation in which a conventionally trained anesthesiologist experiences difficulty with mask ventilation, difficulty with tracheal intubation, or both." Difficult tracheal intubation is defined as "proper insertion of the endotracheal tube with conventional laryngoscopy requires more than three attempts" and "more than 10 min." 17 This definition applies to patients undergoing surgery, usually in the carefully controlled environment of the operating room.

The incidence of difficult intubation in the operating room is often quoted as between 1% and 4%.18 However, the literature frequently confuses difficulty of laryngoscopy with difficult tracheal intubation.19 In most studies, difficult laryngoscopy is defined as that resulting in a view of the larynx corresponding to Cormack and Lehane grades III and IV.20 This occurs during 0.3–13% of laryngoscopies.19,21,22 However, many patients with a grade III laryngoscopic view may have their trachea intubated on the first attempt.19 Although laryngoscopy may be difficult in this group of patients, the trachea is not necessarily difficult to intubate.

The incidence of difficulty in successfully placing the endotracheal tube within the trachea has been less well studied and ranges from 1% to 3.6%.21,22 However, neither the anesthesia nor the critical care literature provides a standard definition of what constitutes a difficult tracheal intubation; this lack of consistency has hampered meaningful investigation.

For the purposes of this study, a difficult tracheal intubation was defined as one that involves more than
two attempts to place the endotracheal tube by an individual with at least 6 months of formal training in anesthesiology. This definition is more applicable to the performance of emergent tracheal intubations in critically ill patients because of the urgency with which this procedure frequently needs to be carried out. In addition, this definition allows for the assessment of the difficulty of intubation when carried out by individuals who have had at least 6 months of training but who are not yet “fully trained.” This definition may be more relevant to institutions in which resident physicians carry out most of the tracheal intubations in both the operating room and the intensive care unit.

Most (89%) of the intubations in this study were accomplished on the first or second attempt at laryngoscopy, even when carried out by residents or fellows with no previous formal training in airway management. Twenty-four intubations met the criteria for a difficult intubation, and two were especially difficult, each requiring ten attempts. However, no increased incidence of adverse patient outcome (aspiration, malpositioning, or death) could be ascribed to the difficulty of tracheal intubation.

The findings regarding the incidence of difficult intubation and the association between these difficulties and the occurrence of complications are different than in previous studies. Zwillich et al. defined prolonged intubation attempt as more than 3 min of laryngoscopy and/or more than three attempts. Using this broader definition, 30% of intubation attempts were prolonged in that study. These prolonged attempts at intubation were associated with “massive” gastric distention and grand mal seizures from presumed “hypoxia produced by the procedure.” Stauffer et al. found that 20% of intubations required four or more attempts, and 31% were longer than 2 min in duration. In addition, a cardiac arrest in one patient was attributed to a prolonged intubation attempt by a house officer. Thus, in both of these reports, the incidence of difficult intubation and associated complications was higher than in this study.

It is possible that the lower incidence of difficult intubation and lack of correlation between difficulty and complications in this study is explained by the educational program and the approach to airway management used in our institution. This approach differs substantially from that used by Zwillich et al. and Stauffer et al. All intubations in critically ill patients at our institution are supervised by either an attending physician or an anesthesia resident. In addition, the duration of each laryngoscopy is strictly limited, and bag and mask ventilation is provided with 100% O2 between attempts; also, cricoid pressure is used to prevent gastric distention and pulmonary aspiration of gastric contents.

**Esophageal Intubation**

An unrecognized esophageal intubation will result in severe hypoxemia progressing to cardiac arrest and ultimately death. After emergent intubation, the confirmation of the intratracheal location of an endotracheal tube is essential to airway management in critically ill patients. A number of techniques are used to document that the endotracheal tube is within the trachea. These include direct visualization of the endotracheal tube passing between the vocal cords, symmetric and bilateral chest movement with ventilation, the auscultation of breath sounds over the lung apices or in the midaxillary region coincident with ventilation, the absence of “breath sounds” over the epigastrium, condensation within the lumen of the endotracheal tube during ventilation, palpation of the cuff of the endotracheal tube in the neck, and noting the normal “feel” of a reservoir bag with ventilation and the refilling of the bag with exhalation. Unfortunately, none of these methods is certain. A decrease in oxyhemoglobin saturation as measured by pulse oximetry might detect an otherwise unrecognized esophageal intubation. However, this recognition may be delayed because of the use of oxygenation before intubation and by alveolar ventilation (with room air) via diaphragmatic movement produced by esophageal intubation and gastric ventilation.

Proper location of the endotracheal tube also can be confirmed using one of a variety of techniques to detect exhaled carbon dioxide. The use of capnography has become the standard of care in anesthesia practice in the operating room. The Society of Critical Care Medicine has recommended that capnography be available in all intensive care units. A number of devices are available to confirm endotracheal tube placement. They include colorimetric techniques and infrared devices. These devices provide useful data in many situations but can yield misleading information. For example, during cardiac cardiopulmonary resuscitation, end-tidal carbon dioxide levels may be low to undetectable because of insufficient pulmonary blood flow produced by inadequate resuscitative efforts.

In this study, all esophageal intubations were detected by clinical examination or pulse oximetry. Clinical evaluation was effective in recognizing 32 of these, whereas the remaining 3 were only detected by a de-
crease in arterial oxygen saturation as measured by pulse oximetry. However, since the completion of the study, we have cared for a patient in whom an esophageal intubation was not detected clinically before death. Therefore, although the detection of exhaled carbon dioxide after tracheal intubation in critically ill patients has not been rigorously studied, we believe it should be used to provide additional confirmatory evidence whenever possible.

**Pneumothorax**

Pneumothorax has been reported by others to be associated with right mainstem intubation and an increase in mortality. In this study, only two pneumothoraces were associated with intubation as demonstrated by the initial postintubation chest radiograph. Neither of the pneumothoraces was under tension, and there was no association between the occurrence of barotrauma, mainstem intubation, or mortality. The differences between these findings and those previously reported are unexplained.

**Aspiration**

Aspiration in this study is defined as a new and unexplained infiltrate seen on the chest radiograph obtained after intubation. The use of this definition might underestimate the incidence of aspiration, because it does not take into account gastric contents visualized at the time of laryngoscopy. However, overestimation is more likely because some of these "new" infiltrates may have developed before airway manipulation. Regardless, the radiographic documentation of a new and/or unexplained infiltrate better reflects the maximum number of clinically significant cases of aspiration. Using this definition, 4% of intubations in this study were associated with aspiration. Interestingly, difficulty with airway management and esophageal intubation were not associated with aspiration.

Cricoid pressure, as described by Sellick, has been shown to be effective in preventing gastric inflation during manual bag and mask ventilation in adults and children, to obliterate the esophageal lumen even when a nasogastric tube is present, and to prevent regurgitation of gastric contents at intragastric pressures of up to 94 cmH₂O. In our study, cricoid pressure was applied during 75% of oral intubations in which an unexplained infiltrate was documented. Although the application of cricoid pressure did not eliminate all episodes of aspiration, its use may have decreased the incidence of this complication of airway management.

**Complications and Supervision**

For the complications of airway management prospectively examined in this study (esophageal intubation, difficult intubation, pneumothorax, aspiration and death), there was no difference in the incidence based on whether the procedure was supervised by an attending physician. This finding is probably due to our policy that all intubations must be supervised by either an attending critical care or anesthesia physician or an anesthesia resident with at least 6 months of training in airway management. This system of airway management probably resulted in a reduction in the complications found in this study (difficulty with airway management and aspiration) in comparison to previously published reports. The findings also suggest that airway management skills can be taught to non-anesthesia physicians using an educational program that focuses specifically on the care of critically ill patients and with the careful supervision of skilled physicians.

In summary, this prospective study of 297 tracheal intubations in critically ill patients identified a significant frequency of major complications including difficult intubation (8%), esophageal intubation (8%), aspiration (4%), and pneumothorax (1%). Because these complications were rapidly recognized and treated, none led to a patient death. However, a high mortality (15%) was associated with tracheal intubation in patients with systemic hypotension, even though the patients did not receive any sedative or hypnotic agents to facilitate intubation. These data suggest that the patient's hemodynamic profile can serve as a predictor of mortality to stratify the risk of mortality associated with emergent intubation in both clinical practice and for comparative studies. There was no increased incidence of any of the major complications when intubations were accomplished without the supervision of an attending physician as long as tracheal intubation in critically ill adults is carried out or supervised by a physician trained in airway management for at least 6 months.

**References**