Clinical Predictors of Prolonged Translaryngeal Intubation in Patients with the Adult Respiratory Distress Syndrome*

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This study was designed to determine if clinical features apparent after seven days of mechanical ventilation predict long-term intubation beyond 14 days and subsequent need for tracheotomy in patients with ARDS. Twenty-four patients were entered into the study. Group 1 patients were successfully extubated in ≤14 days after onset of ARDS and group 2 patients remained intubated >14 days. On day 7 of ARDS, group 1 had a higher PaO2/FIO2 ratio, a lower PEEP requirement, less severe chest radiographic abnormalities and a greater likelihood of an improved radiograph from the baseline study. None of group 1 and 11 group 2 patients eventually underwent tracheotomy. Clinical features apparent after seven days of mechanical ventilation in patients with ARDS suggest the likelihood of prolonged intubation beyond 14 days and eventual tracheotomy. Recognition of these features may allow more timely conversion of endotracheal intubation to tracheotomy.

(Chest 1990; 97:447-52)

ARDS = adult respiratory distress syndrome; PEEP = positive end expiratory pressure; PaO2 = arterial oxygen pressure; PaO2/FIO2 = alveolar oxygen pressure; ET = endotracheal tube; Caw = total thoracic compliance; Pw = pulmonary capillary wedge pressure; Pp = barometric pressure; Ps = static airway pressure at end-inspiration; ANOVA = analysis of variance

Although tracheotomy is a venerable procedure with historic roots in ancient history, it continues to provide important applications in critically ill patients today. A major indication for tracheotomy is airway cannulation in patients with respiratory failure requiring long-term mechanical ventilation. Although tracheotomy provides clear benefits in this clinical setting, controversy exists regarding the optimal timing of conversion from a translaryngeal ET to tracheotomy in ventilator-dependent patients.5,9

Although current recommendations emphasize that the decision for tracheotomy should be individualized and not based on an arbitrary duration of preceding ET intubation, most patients undergo tracheotomy after 14 to 21 days of mechanical ventilation.9 Recognizing that this duration of ET intubation promotes patient discomfort, interferes with nursing care and risks serious laryngeal injury,2,10,11 patients should undergo tracheotomy earlier in the course of respiratory failure if long-term intubation and eventual tracheotomy appear inevitable.5 Unfortunately, no studies indicate that clinical features apparent in the early course of respiratory failure assist physicians in accurately predicting the duration of ventilator dependency.

We, therefore, examined the courses of patients with one form of respiratory failure, ARDS, and determined whether clinical features apparent after seven days of intubation predicted the likelihood of continued airway cannulation beyond 14 days and the subsequent need for tracheotomy. The existence of clinical predictors of eventual tracheotomy would allow more timely performance of the procedure and improve patient tolerance of prolonged intubation.

METHODS

All medical records coded with the diagnosis of ARDS during a period from 1983 to 1987 were reviewed for inclusion in the study. Patients were considered to have ARDS when all the following criteria were fulfilled: occurrence of an event or condition recognized as a risk factor for ARDS, acute onset of respiratory failure requiring intubation and mechanical ventilation, rapid development of bilateral diffuse interstitial or alveolar infiltrates, initial Pw ≤ 18 mm Hg, total static Caw ≤ 50 ml/cm H2O immediately after initiation of mechanical ventilation, and PaO2/FIO2 < 150 mm Hg (< 200 mm Hg for patients receiving some degree of PEEP). Patients fulfilling the criteria for ARDS were included in the study if they continued to require intubation for at least seven days after the onset of ARDS, and if they survived an additional seven days to day 14 of respiratory failure. Survival to the 14th day of ARDS was a necessary entrance criterion so as to allow determination of the presence or absence of prolonged intubation, which was defined as >14 days.

The study patients were divided into two groups on the basis of

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Table 1—Clinical Features on Day 0 of Study Patients Requiring Intubation for ARDS*

<table>
<thead>
<tr>
<th></th>
<th>All Study Patients (n = 24)</th>
<th>Group 1 (n = 10)</th>
<th>Group 2 (n = 14)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age, yr</td>
<td>41.4 ± 4.1</td>
<td>40.5 ± 5.6</td>
<td>42.1 ± 6.4</td>
<td>NS</td>
</tr>
<tr>
<td>Women, n</td>
<td>14</td>
<td>7</td>
<td>7</td>
<td>NS</td>
</tr>
<tr>
<td>PEEP value, cm H₂O</td>
<td>8.8 ± 1.1</td>
<td>9.9 ± 1.8</td>
<td>8.0 ± 1.4</td>
<td>NS</td>
</tr>
<tr>
<td>PaO₂/FIO₂</td>
<td>121.9 ± 13.3</td>
<td>113.2 ± 5.1</td>
<td>99.8 ± 12.7</td>
<td>NS</td>
</tr>
<tr>
<td>C₄₅₀, ml/cm H₂O</td>
<td>24.8 ± 2.2</td>
<td>23.0 ± 2.8</td>
<td>28.0 ± 2.9</td>
<td>NS</td>
</tr>
<tr>
<td>PS, mm Hg</td>
<td>12.5 ± 0.5</td>
<td>13.4 ± 0.6</td>
<td>11.9 ± 0.7</td>
<td>NS</td>
</tr>
<tr>
<td>BUN, mg/dL</td>
<td>23.0 ± 3.1</td>
<td>26.2 ± 4.9</td>
<td>24.2 ± 16.2</td>
<td>NS</td>
</tr>
<tr>
<td>Serum creatinine, mg/dL</td>
<td>2.2 ± 0.5</td>
<td>2.2 ± 0.7</td>
<td>1.9 ± 0.6</td>
<td>NS</td>
</tr>
<tr>
<td>Hematocrit, %</td>
<td>32.5 ± 1.2</td>
<td>33.2 ± 2.8</td>
<td>32.0 ± 1.0</td>
<td>NS</td>
</tr>
<tr>
<td>Leukocyte count, 10⁹ cells/µL</td>
<td>14.0 ± 1.3</td>
<td>16.3 ± 2.7</td>
<td>11.7 ± 1.5</td>
<td>NS</td>
</tr>
</tbody>
</table>

*All values are mean ± SEM.

their duration of intubation and mechanical ventilation. Group 1 patients required endotracheal intubation for >7 days but ≤14 days, and group 2 patients required endotracheal intubation for >14 days.

Daily clinical information was obtained from the medical records beginning with day 0, which was defined as the first day that patients fulfilled diagnostic criteria for ARDS. Day 0 data were obtained from medical record information charted either immediately after nonintubated patients underwent intubation and initiation of mechanical ventilation for respiratory failure, or after patients already intubated for other indications fulfilled diagnostic criteria for ARDS. Clinical information on subsequent hospital days was extracted from data charted daily between 0600 and 0800 in nursing notes, ICU charts, laboratory reports and respiratory therapy records.

Total static thoracic compliance was calculated by dividing the actual exhaled tidal volume (VT) by the Pₜ; C₄₅₀ = VT/Pₜ-PEEP). The VT was corrected by subtracting tube compression volume from the measured VT.

The progression of hypoxemia was determined by calculating the ratio of PaO₂ to PaO₂ utilizing the alveolar gas equation:

$$\text{PaO}_2/\text{PaCO}_2 = \text{PaO}_2/(P_\text{A} - P_{\text{A}-\text{PEEP}}) = \text{PaCO}_2/0.8$$

where Pₜ = sea-level Pₜ (760 mm Hg) and Pₜ₋₄ₒ = water vapor pressure (47 mm Hg).

Chest radiographs were available from six of the ten group 1 patients and from 14 of the group 2 patients. Day 0 radiographs were evaluated as a part of the diagnostic criteria for ARDS. Day 7 radiographs were graded in a blinded fashion by both investigators independently using two scoring systems. The first system determined whether the severity of pulmonary infiltrates was improved, unchanged or worse on day 7 compared with day 0. The second system determined whether the day 7 chest radiograph was normal or demonstrated diffuse interstitial infiltrates, alveolar infiltrates involving <50 percent of the lung fields, or alveolar infiltrates involving ≥50 percent of the lung fields. A numerical severity score of 1 through 4 was applied to the increasing severity of the radiographic findings to allow statistical comparisons between groups. Results of the readers' scores were averaged.

All data are expressed as mean ± SEM except for range of values where noted. Statistical significance between groups was determined using unpaired Student's t test. Differences between groups in PEEP and PaO₂/PaCO₂ values over time were compared using two-way ANOVA. A p value <0.05 was considered significant.

Results

Of the 126 patient charts reviewed, 24 patients met criteria for entrance into the study. The 102 patients who were excluded (1) never fulfilled diagnostic criteria for ARDS (41 patients), (2) were extubated on or before the seventh day of ARDS (21 patients), or (3) died before the 14th day of ARDS (40 patients).

Clinical information pertaining to the entire study group is reported in the first column of Table 1. The mean age was 41.4 ± 4.1 years and women predominated.
nated (14 women vs 10 men). The patients' underlying clinical disorders and conditions that precipitated ARDS are listed in Table 2.

Ten patients were successfully extubated on or before day 14 of ARDS (group 1), and 14 patients required intubation for ARDS longer than 14 days (group 2). Severity of respiratory failure between group 1 and 2 patients at the outset of ARDS was similar as determined by $C_{\text{t}}$, $P_{aO_2}/P_{aCO_2}$, PEEP requirements on day 0 (Table 1), and chest radiographic appearance. Only one study patient, who was in group 1, was not on PEEP at the first $P_{aO_2}$ determination. There were proportionately more women in group 1 (seven of ten patients) than in group 2 (seven of 14 patients) although differences did not reach statistical significance. No differences between group 1 and 2 patients in age, initial $P_{aO}$, indices of renal function, hemogram values (Table 1) or incidence of sepsis (Table 2) were noted. Only one study patient (who was in group 2) was unconscious with poor airway control on day 7; this patient, however, also had continued severe respiratory failure (PEEP $>10$ cm H$_2$O, 100 percent dense alveolar infiltrates and $P_{aO_2}/P_{aCO_2} = 0.34$) on day 7 as an indication for prolonged intubation similar to other group 2 patients.

Group 1 patients demonstrated more rapid improvement in pulmonary oxygenation compared with group 2 resulting in a significantly higher $P_{aO_2}/P_{aCO_2}$ on day 7 ($0.50 \pm 0.04$ vs $0.34 \pm 0.03$, $p < 0.005$) (Fig 1). Eight of ten group 1 and six of 14 group 2 patients had $P_{aO_2}/P_{aCO_2}$ on day 7 $>0.40$. The improved oxygenation in group 1 was associated with a more rapid decrease in administered PEEP levels and a lower PEEP requirement on day 7 compared with group 2 (3.7 $\pm$ 0.9 vs 9.3 $\pm$ 1.4 cm H$_2$O, $p < 0.005$) (Fig 2). None of ten group 1 patients and ten of 14 group 2 patients had day 7 PEEP values $>10$ cm H$_2$O. No significant differences existed between group 1 and 2 patients in day 7 values of $C_{\text{t}}$ (28.7 $\pm$ 4.1 vs 29.5 $\pm$ 3.6 ml/cm H$_2$O) or $F_{iO_2}$ (0.41 $\pm$ 0.02 vs 0.52 $\pm$ 0.04).

Despite an initial similarity of chest radiographic abnormalities on day 0, more group 1 (six of six patients) compared with group 2 patients (three of nine patients, $p < 0.017$) demonstrated improvement of pulmonary infiltrates on day 7. Furthermore, the severity score of day 7 radiographs exhibited less severe abnormalities in group 1 (2.0 $\pm$ 0.4) compared with group 2 (3.6 $\pm$ 0.3, $p < 0.005$) patients (Fig 3). None of six group 1 and seven of nine group 2 patients had day 7 radiographs with $>50$ percent of lung fields involved with dense alveolar infiltrates. There was a 100 percent agreement between readers regarding presence of chest radiograph improvement and a 96 percent agreement in scoring chest radiograph severity.

Group 1 patients were intubated and mechanically ventilated for ARDS for 9.7 $\pm$ 0.7 days (range, 8 to 14
Predictors of Prolonged Intubation in ARDS (Heffner, Zamora)

days) and remained in the ICU for 12.5 ± 1.3 days (range, 9 to 19 days). No group 1 patient underwent tracheotomy or required reintubation after early extubation. Eight of 10 group 1 patients survived their illness and left the hospital after 26.3 ± 5.7 days (range, 15 to 64 days).

Group 2 patients were intubated with translaryngeal tubes for 20.6 ± 2.9 days (range, 7 to 51 days, p < 0.002). Eleven of 14 group 2 patients underwent tracheotomy after 20.6 ± 3.4 days (range, 7 to 51 days) of translaryngeal intubation for ARDS. Tracheotomy was considered first and arrangements initiated for surgery in these 11 patients after 17.5 ± 3.8 days of respiratory failure. Three patients had a tracheotomy placed before day 14 (days 7, 12 and 13) because of difficulties with translaryngeal tubes. All three of these patients died after 15, 19 and 48 days of intubation. The remaining three group 2 patients who did not receive a tracheotomy died after 16, 16 and 30 days of translaryngeal intubation. Group 2 patients were maintained on mechanical ventilation for 42.4 ± 8.1 days (p < 0.002) and remained in the ICU for 43.4 ± 8.0 days (p < 0.003). Only four of 14 group 2 patients survived their illnesses and were discharged from the hospital after 62.8 ± 15.7 days (range, 42 to 109 days, p < 0.002) of ARDS. The remaining 11 group 2 patients expired after 38.2 ± 8.6 days (range, 16 to 109 days) of ARDS. No group 2 patient underwent attempted extubation before day 28 of ARDS.

The sensitivity, specificity and predictive values of day 7 clinical features in predicting the need for prolonged intubation are displayed in Table 3.

**DISCUSSION**

The present study demonstrates that clinical features apparent after seven days of mechanical ventilation for ARDS can determine the likelihood that successful extubation will occur within the following seven days. Presence on day 7 of a PaO2/PaO2 ratio ≥0.40, a PEEP requirement below 10 cm H2O, an improving chest radiograph and less than 50 percent of lung field involvement with alveolar infiltrates was associated with early recovery from respiratory failure in group 1 patients. Conversely, absence of these features after seven days of management for ARDS identified group 2 patients who subsequently required long-term mechanical ventilation. Furthermore, group 2 patients were likely to undergo eventual tracheotomy. The nature of the underlying clinical predisposition to ARDS, the severity of initial respiratory failure or the degree of improvement in thoracic compliance after seven days of ARDS were not predictive of intubation duration.

The reviewed medical records did not clearly indicate whether the physicians' decisions to extubate patients were based on specific weaning criteria that incorporated spontaneous ventilatory parameters. Nevertheless, no group 1 patient required reintubation after undergoing extubation on or before day 14 of ARDS; this finding demonstrates the accuracy of categorizing these patients into group 1. Furthermore, no group 2 patient underwent attempted extubation during the first 28 days of ARDS; this observation suggests that no patient was categorized into group 2 because he or she remained on mechanical ventilation needlessly beyond day 14. Rather, the severity of respiratory failure and the rapidity of resolution of ARDS appeared to be the major factors determining timing of extubation.

The observations of this study objectify our clinical impression that patients who are successfully extubated within 14 days of ARDS begin to experience recovery of lung function within the first several days of respiratory failure. Indeed, the differences in PaO2/PaO2 and PEEP requirements first became significantly different between groups by day 2 and day 5 of ARDS, respectively. Either progressive deterioration or lack of significant improvement requiring ongoing aggressive respiratory support by the seventh day of pulmonary dysfunction identify patients with more severe ARDS. Such patients usually do not improve rapidly within the following few days to allow early extubation. Recognition of these predictive clinical features after the first week of mechanical ventilation allows timely patient care planning, such as the decision to perform a tracheotomy.

The proper timing of tracheotomy in patients with respiratory failure undergoing mechanical ventilation

<table>
<thead>
<tr>
<th>Table 3—Sensitivity and Specificity of Day 7 Clinical Features in Determining Need for Intubation beyond 14 Days in the Study Patients</th>
<th>Predictive Value</th>
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<tbody>
<tr>
<td></td>
<td>Sensitivity (%)</td>
</tr>
<tr>
<td>PEEP &gt;10 cm H2O</td>
<td>71</td>
</tr>
<tr>
<td>PaO2/PaO2 &lt;0.40</td>
<td>57</td>
</tr>
<tr>
<td>No radiographic improvement</td>
<td>67</td>
</tr>
<tr>
<td>&gt;50% lung fields with radiographic alveolar infiltrates</td>
<td>78</td>
</tr>
</tbody>
</table>

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is controversial. Proponents of either “early” or “late” tracheotomy focus on the relative risks of prolonged translaryngeal intubation as opposed to surgical airway cannulation. Both procedures, however, have inherent complications. Tracheotomy presents surgical risks, such as stoma infection and hemorrhage, and long-term hazards, such as tracheal stenosis and tracheoinnominate fistulae. Recent studies, however, suggest that perioperative complications occur in only 2 to 6 percent of patients when tracheotomy is performed by experienced surgeons. In comparison, prolonged ET intubation complicates nursing care, promotes patient discomfort, induces sinus infection during nasal cannulation, and risks laryngotracheal stenosis, which is less readily correctable by surgery than tracheal injury from tracheotomy. The incidence of long-term airway injury from prolonged ET intubation is similar to that reported from tracheotomy in recent studies.

Attempting to balance relative complications and recognizing the benefits of tracheotomy in long-term ventilation, recent literature and common practice have recommended that patients may remain translaryngeally intubated with relative safety for 14 days, after which a tracheotomy should be performed if extubation is not imminent. This timing is supported by observations that irreversible laryngeal injury from translaryngeal ETs becomes cumulative by day 10 of intubation. Furthermore, the risks of laryngeal injury from tracheotomy appear directly related to the duration of preceding ET intubation before surgery. Therefore, once a tracheotomy appears inevitable, it should be performed as soon as possible, thereby limiting the degree of laryngeal inflammation and patient discomfort from ET intubation.

The recommendation to limit ET intubation to 14 days has been transformed in many institutions into the clinical practice of avoiding consideration of tracheotomy until a requisite 14 days of intubation prompts the issue. This practice, as demonstrated by the present study, frequently delays the actual performance of tracheotomy beyond two to three weeks. These delays may result from surgical scheduling difficulties and by the clinician’s recurrent unrealistic expectations that extubation will occur in “another few more days.” Recognition of the clinical features identified in this study may avoid subjecting patients with ARDS to an unnecessary gauntlet of 14 or more days of ET intubation if the need for long-term intubation and eventual tracheotomy is evident on day 7. Patients not fulfilling day 7 criteria for prolonged ventilation can be reevaluated daily in an effort to proceed to extubation and avoid tracheotomy.

The majority of group 2 patients who required prolonged intubation died during their hospitalization for ARDS. The importance of recognizing the need for earlier tracheotomy persists, however, because the majority of these patients remained mentally alert and survived from 16 to 109 days after intubation. Tracheotomy, however, was not implemented for 7 to 51 days after onset of respiratory failure. Since tracheotomy was eventually performed in an effort to improve patient comfort, facilitate communication and assist nursing care, these benefits would have contributed to well-being for a greater portion of these patients. Hospitalizations had the tracheotomy not been delayed.

We limited the study to patients with ARDS because the clinical course, complications and outcome of patients with respiratory failure from diverse disorders such as ARDS, emphysema, neuromuscular disease and pneumonia differ sufficiently to affect clinical predictors of intubation duration. Consequently, however, conclusions from the present study may not apply to patients undergoing mechanical ventilation who experience respiratory failure from etiologies other than ARDS. Additional studies investigating early clinical predictors of prolonged intubation in other conditions associated with respiratory failure are warranted.

In conclusion, previous studies indicate that most patients with ARDS should undergo initial intubation with ET tubes with the goal of achieving extubation within 14 days. The necessity of long-term intubation and likelihood of eventual tracheotomy, however, can be determined from clinical features apparent after seven days of ARDS, thereby allowing selection of patients for early tracheotomy. Although the specific clinical features that suggest prolonged intubation are interdependent to a degree, they serve to identify patients with severe ARDS who do not rapidly improve between the 7th and 14th days of respiratory failure. This approach avoids prolonging ET intubation in patients once eventual tracheotomy appears inevitable.

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