Extubation Failure in a Large Pediatric ICU Population*

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Objective: To review a large population of children receiving mechanical ventilation to establish a baseline rate of extubation success and failure and to identify those characteristics that place a patient at greater risk of failing planned extubation.

Design: Retrospective chart review.

Setting: University-affiliated children’s hospital with a 20-bed pediatric ICU.

Patients: All 632 patients receiving mechanical ventilation during the 2-year period from July 1, 1996, to June 30, 1998.

Method: Patients receiving mechanical ventilation were identified via a computerized database. Charts were reviewed of all patients who were reintubated within 72 h of extubation.

Measurements and results: There were 548 planned extubation events, of which 521 were successful. Twenty-seven patients failed planned extubation at least once; only the first attempt at extubation was included in the analysis. The failure rate of planned extubations was 4.9%. Including only patients who had received mechanical ventilation for > 24 h before extubation, the failure rate was 6.0%. For patients intubated > 48 h, the failure rate was 7.9%. The patients who failed extubation were found to be significantly younger and to have received mechanical ventilation longer than those who succeeded, in both the analysis of all patients receiving mechanical ventilation and the subgroup of those receiving mechanical ventilation > 24 h. When only patients who had received mechanical ventilation for > 48 h were analyzed, the difference in age was no longer significant, but the duration of ventilation before extubation was still significantly longer for those who failed.

Conclusion: We determined the overall failure rate of planned extubations in a large population of pediatric patients to be 4.9%. Those patients who were younger and had received mechanical ventilation longer were more at risk for extubation failure.

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Key words: artificial respiration; child; infant; respiratory failure

Abbreviation: PICU = pediatric ICU

Mechanical ventilation is a lifesaving mainstay of therapy in pediatric critical care. Because of the numerous complications and side effects associated with this therapy,1–3 it is widely recognized as advantageous to remove the patient from this mode of support as early in the clinical course as possible. Extubation failure and reintubation, however, are also associated with significant risks, including an increased incidence of pneumonia,4 prolonged stay in the ICU,4,5 and increased mortality.4–6

Extensive efforts have been made to identify predictors of successful weaning and extubation. In the adult literature, weaning indexes based on integration of direct measurements of pulmonary function have been developed.7 Attempts to apply these indexes to pediatric patients have met with mixed results.8–10 A review of the pediatric literature fails to reveal a large study determining a baseline rate of extubation failure against which to compare the results of these attempts to establish predictors of extubation outcome. In adult studies, rates of extubation failure range from 1.8 to 18.6%.6,11–13 In the pediatric literature, studies evaluating predictors of weaning outcome have shown rates of extubation failure ranging from 16 to 22%.8–10,14 Most of these studies are relatively small, with populations of 47 to 208 children, and vary in design in several significant ways that make the data difficult to interpret. Several studies excluded patients with upper airway obstruction from their analysis,9,14 whereas elsewhere stridor is cited as the causative factor in as many as 11 to 20% of extubation failures.15,16 The studies also differ in the duration of mechanical ventilation be-
before attempted extubation required for inclusion into the study, with all receiving mechanical ventilation patients included in some studies and a minimum of 24 to 48 h of ventilation required in others.

We undertook a review of pediatric patients receiving mechanical ventilation to establish a baseline rate of extubation failure. We also sought to establish that the presence of certain risk factors, namely younger age and longer duration of mechanical ventilation, would place the patient at higher risk of extubation failure.

**Materials and Methods**

This retrospective chart review was approved by the Human Subject Protection Committee. A database listing all patients requiring mechanical ventilation in the pediatric ICU (PICU) at the University of California, Los Angeles between July 1, 1996, and June 30, 1998, was cross-referenced with a list of all dates of intubations performed. Charts were reviewed of all patients requiring reintubation within 72 h of having been extubated.

Forty-one percent of the patient population at the University of California, Los Angeles can be characterized as general PICU, 26% cardiac (both postoperative and nonoperative cardiac disease), 21% neurosurgical or neurovascular, 9% orthotopic liver transplant, and 3% hematology or oncology. Because of the limitations of the database, a more specific description of the patients under review is not available.

Data collected from chart review included age, duration of mechanical ventilation, time until reintubation, and reason cited for failure. In cases in which patients failed extubation more than once, only the first attempt was included in the analysis.

**Statistical Analysis**

Distribution of age and duration of ventilation was not found to be normal (parametric) in either the group of patients who were successfully extubated or the group who failed, and Bartlett’s test indicated nonhomogeneous variance. The Mann-Whitney test was conducted for comparison of both age and days of mechanical ventilation. The means are expressed as mean ± SD.

**Results**

There were 632 patients requiring mechanical ventilation during the period under review. Of these, 70 died without ever having been extubated, leaving 562 patients. Fourteen patients were unintentionally extubated, leaving 548 patients in the study. Only the first attempt at extubation was included in the analysis. The mean age of the group (± SD) was 52.4 ± 61.4 months, with a median of 22.6 months. Mean number of ventilator days before extubation was 6.5 ± 17.1 days, with a median of 2 days.

Of the 548 patients who were intentionally extubated, 521 attempts were successful and 27 were unsuccessful, giving an overall failure rate for planned first extubations of 4.9%. Six of the 27 patients who failed extubation went on to fail a second time, and no patient failed more than twice; these second attempts were excluded from the analysis. Those patients who failed intentional extubation differed from those who succeeded in both age and days of mechanical ventilation. Those who failed received mechanical ventilation longer than those who succeeded (12.2 ± 9.0 days; median, 10 days vs 6.2 ± 17.4 days; median, 1 day; p < 0.0001). They were also considerably younger (26.2 ± 43.9 months; median, 8 months) than those who succeeded (53.7 ± 61.9 months; median, 23.9 months; p = 0.0130).

We then performed the same analysis on the subgroup of patients who had been receiving mechanical ventilation for ≥ 24 h before attempted extubation. There were 444 extubations, of which 417 were successful and 27 unsuccessful, for a failure rate of 6.0%. Again, patients who failed differed from those who succeeded in both age and days of mechanical ventilation. Patients who failed extubation had been receiving mechanical ventilation longer (12.2 ± 9.0 days; median, 10 days vs 7.7 ± 19.1 days; median, 2 days) than those in the successful group (p < 0.0001). They were also significantly younger than those who succeeded (26.2 ± 43.9 months; median, 8 months vs 51.1 ± 60.6 months; median, 20.9 months; p = 0.0273).

When only patients who had required mechanical ventilation for > 48 h were included, there were 280 extubations; 258 were successful and 22 unsuccessful. The overall failure rate for this group was 7.9%. Again, the patients who failed extubation were found to have been receiving mechanical ventilation for significantly longer than those who succeeded (14.7 ± 8.0 days; median, 14 days vs 11.9 ± 23.4 days; median, 5 days; p < 0.0001). Although the patients who failed extubation in this subgroup tended to be younger (28.0 ± 47.7 months; median, 8.5 months vs 46.8 ± 57.8 months; median, 17.8 months), this difference was no longer significant (p = 0.1798). Results are summarized by duration of ventilation in Table 1.

Charts were also reviewed to determine the reasons cited for extubation failure and for the duration of the extubation trial before reintubation. Interventions attempted before reintubation often included trials of continuous positive airway pressure, biphasic positive airway pressure, or helium-oxygen administration, on the basis of clinical indication. Stridor was the most commonly cited reason for failure, with 6 of the 27 extubations failing for that reason. Other reasons cited for extubation failure included hypoxemia (n = 7), respiratory distress (n = 4), depressed level of consciousness (n = 2), apnea (n = 2), and one each for seizures, pleural effusion, hemidiaphragmatic paralysis, congestive heart failure, thick
secrections, and metabolic acidosis. The average length of time before reintubation was 18.3 h, with a median of 8 h; the range was 10 min to 72 h. Of patients who required reintubation, 70% failed within the first 24 h. All patients who failed secondary to stridor failed within the first 16 h of extubation. One patient who failed twice secondary to stridor required tracheostomy.

**Discussion**

Many factors influence a patient’s ability to tolerate extubation. The ability to maintain adequate gas exchange is affected by central inspiratory drive, respiratory muscle strength, and the workload placed on the muscles of respiration.9,17,18 The positive and negative predictive values of physicians’ clinical judgment alone in predicting extubation outcome in adult patients was found to be 50% and 67%, respectively.19 The predictive accuracy of direct measurements of pulmonary function have been reviewed in numerous adult studies.13,20–22 In addition, predictive indexes that integrate several physiologic functions have been developed and studied in adults. Application of these indexes to pediatric populations has met with mixed results. Baumeister et al8 adapted the integrated indexes to pediatric patients by normalizing the tidal volume and dynamic compliance to body weight. Extubation failure was defined as reintubation within 24 h; the failure rate in this study was 19%. In a study of 208 pediatric patients who had been intubated for ≥ 24 h, Khan et al9 identified criteria for a low risk (< 10%) and a high risk (25%) of extubation failure on the basis of direct measurements of pulmonary function. Overall failure rate in this study, defined as reintubation within 48 h, was 16.3%, excluding those failing secondary to upper airway obstruction.

Farias et al8 found that three fourths of their pediatric patients were successfully extubated after the completion of a 2-h trial of spontaneous breathing. Nine percent of the patients failed the trial and were not extubated; 16% of the patients who passed the trial and were extubated failed extubation within 48 h. As in our study, patients who failed extubation were found to be significantly younger than patients who succeeded.

Several anatomic and physiologic factors may contribute to the high failure rate noted among the younger patients in our study. The subglottic larynx is the most narrow portion of the infant’s airway and is vulnerable to mucosal irritation and inflammatory edema with endotracheal intubation. Stridor was, in fact, the most common reason cited for extubation failure in our study. The infant is also at a mechanical disadvantage because of the high compliance and low elastic recoil of the infant chest wall. The infant must perform more work to move the same tidal volume as a more mature patient, as part of the work of breathing is lost in distortion of the ribcage. The low elastic recoil of the chest wall places the infant at greater risk of lung collapse as most tidal breathing takes place in the range of the closing capacity of the lung.23

Our study represents the largest series of pediatric patients for which a baseline rate of extubation failure has been established. The percentages of patients failing extubation in our series for all patients, for those receiving mechanical ventilation > 24 h, and for those receiving mechanical ventilation > 48 h, are 4.9%, 6.0%, and 7.9%, respectively. It is unclear why our study revealed a rate of failure so much lower than the rates previously noted in other pediatric studies. Decisions to extubate were made in all cases with pediatric critical care faculty input. Decisions were subjective and based on clinical indicators of ability to tolerate extubation, including resolution of the underlying disease process, degree of sedation, quantity and quality of secrections, fraction of inspired oxygen, the patient’s respiratory rate, degree of support being provided by the ventilator, peak inspiratory pressure, and blood gas analysis. Although our patient population is typical of that of a tertiary-care PICU, our database did not permit identification of the specific indicators for intubation for the individual patients; this limits our ability to further characterize the patients at risk for failure.

The question arises as to what is the “optimal” rate of extubation failure. Both exposure to excessively prolonged mechanical ventilation and the stresses of extubation failure and the associated reintubation place the patient at risk. Perhaps our current practice represents an overly cautious standard for trials of extubation. It has been noted that as many as 50% of adult patients who spontaneously extubate do not

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**Table 1—Results for Extubation Events**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Receiving Mechanical Ventilation &gt; 24 h</th>
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<tr>
<td>Age and ventilator days expressed as mean ± SD.</td>
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<tr>
<td>Failure rate, No. (%) 27 (4.9)</td>
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<tr>
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<tr>
<td>p value 0.0130</td>
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<td>Age, mo</td>
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require reintubation. DeHaven et al found that 23 of 26 patients who did not meet weaning criteria were successfully extubated. Perhaps the appropriate goal is to minimize ventilator days, rather than to achieve an extremely low rate of reintubation. Although the most accurate predictor of extubation outcome in pediatric patients has yet to be established, the incorporation of daily systematic consideration for a trial of extubation may prove to be of benefit. From our results, the population most at risk for failure would include the young infants as well as those patients who have been receiving mechanical ventilation for a longer period of time; these patients may warrant closer scrutiny before attempted extubation.

REFERENCES
2 Benjamin PK, Thompson JE, O'Rourke PP. Complications of mechanical ventilation in a children's hospital multidisciplinary intensive care unit. Respir Care 1990; 35:873–878