Peak Flow Rate During Induced Cough: A Predictor of Successful Decannulation of a Tracheotomy Tube in Neurosurgical Patients
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Peak Flow Rate During Induced Cough: A Predictor of Successful Decannulation of a Tracheotomy Tube in Neurosurgical Patients

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Background An accurate predictor of successful decannulation in neurosurgical patients that indicates the best time for tracheotomy decannulation would minimize the risks of continued cannulation and unsuccessful decannulation.

Objective To determine whether the peak flow rate during induced cough is an appropriate predictor of successful decannulation.

Methods A total of 32 neurosurgical patients with a tracheotomy were enrolled. The highest peak expiratory flow rate during 3 induced coughs, the total volume of tracheal secretions collected in 6 hours, and scores on the Glasgow Coma Scale were recorded. Logistic regression analysis was applied to determine the relationship between these variables and successful decannulation (reintubation not required within 72 hours).

Results Decannulation was attempted in 23 of 32 patients. The remaining 9 patients were considered clinically inappropriate for the procedure. Of the 23 patients decannulated, 2 required reinseration of the tracheotomy tube. Analysis revealed that peak flow rate during induced cough (odds ratio, 1.12; 95% confidence interval, 1.02-1.23) was independently associated with successful decannulation (accuracy, 75%; sensitivity, 85.7%; specificity, 54.5%). The receiver operating characteristic curve indicated an optimal cutoff point of 29 L/min.

Conclusion Measurement of peak flow rate during induced cough is a simple and reproducible intervention that improves predictability of successful decannulation in patients with tracheotomy. (American Journal of Critical Care. 2010;19:278-284)
Decannulation is the process of removing the tracheotomy tube and allowing patients to breathe by using their own airway. Unsuccessful decannulation (reintubation is required) may result in tracheal ulceration, tracheitis, and recurrent aspiration. Accurate prediction of a successful decannulation should minimize multiple attempts to decannulate a patient.

Two predictors of successful tracheal extubation during weaning from mechanical ventilation are strength of cough and presence of secretions. Depressed mental function, as indicated by the score on the Glasgow Coma Scale (GCS), is a predictor of extubation outcome in patients with brain injuries. The relationship between peak flow rate during cough and decannulation outcome was reported in only a single study, but the cough was assisted by a passive manual abdominal thrust. The relationship between peak flow rate from an unassisted cough reflex and decannulation outcome has not been studied.

Clinical indicators such as no cough reflex or depressed cough reflex and coexisting multiorgan failure are predictive of a poor decannulation outcome, and the decision not to proceed with decannulation is straightforward. Identification of accurate predictors of decannulation outcome may help minimize cannulation time and assist in the clinical decision to decannulate patients who are in the “borderline” category, thereby minimizing the risk of infection associated with prolonged intubation and protecting patients from the trauma of an unsuccessful decannulation. Therefore, we investigated whether the peak flow rate during induced cough (cough peak flow rate, or CPFR) was an appropriate predictor of successful decannulation in neurosurgical patients with a tracheostomy.

Methods

Approval to conduct the study was obtained from the appropriate institutional review board. Patients admitted to the adult neurosurgical units from March 2006 to January 2007 who required a tracheotomy were considered eligible for the study. Those patients referred to physiotherapists by the attending doctors to be assessed for removal of the tracheotomy tube were recruited to join the study. The inclusion and exclusion criteria are displayed in Table 1.

Volume of tracheal secretions, GCS score, and CPFR were measured on the day that a decision on tracheotomy decannulation was made. All measurement procedures were conducted by the same investigator, who did not know the decision on decannulation. Tracheal secretions were collected into a 25-mL suction trap by using a 12F suction catheter with 120 mm Hg of negative suction pressure. The volume of tracheal secretions was measured with a 6-mL graded syringe. Tracheal secretions were collected 4 times: at 9:30 AM, 11:30 AM, 1:30 PM, and 3:30 PM. The patient’s GCS score was assessed at 2:00 PM, immediately before the measurement of CPFR. Following the practice of the local hospital, the attending doctor referred the patient to the physiotherapist for “decannulation assessment.” Therefore, all measurements were performed by the physiotherapist on the day before decannulation. Only daytime measurements were taken because these patients did not require physiotherapy treatments after hours.

For measurement of CPFR, the patient was positioned supine with the head of the bed elevated at 30°. The usual practice for management of neurosurgical patients at the involved hospital was to change the tracheotomy tube from a cuffed to a noncuffed tube before decannulation was considered.

Identification of accurate predictors of decannulation outcome may help minimize cannulation time.
Therefore, patients with a cuffed tracheotomy tube had the cuff deflated before measurements were made. Suctioning above the cuff was done before the cuff was deflated. Oxygen saturation and signs of respiratory distress were monitored during the measurement process. The CPFR measurement procedure was stopped immediately if any of the following occurred: respiratory rate, greater than 35/min; oxygen saturation as measured by pulse oximetry, less than 90%; heart rate, greater than 140/min or an increase of more than 20% above resting levels. With sterile conditions, a standardized proportion (12 cm) of a 10F suction catheter was introduced through the suction port of the swivel elbow connector (DHD Healthcare, Wampsville, New York). The swivel connector with the suction catheter partially inserted was then attached to the patient’s tracheotomy tube, which was in turn connected to a viral/bacterial respiratory filter (GTS, Hong Kong), allowing a pneumotachograph-calibrated Piko-I Electronic Peak Flow Meter (Pulmonary Data Services, Louisville, Kentucky) to be placed in series (Figure 1).

The patient’s breathing pattern was observed. Near the end of an inspiration, the suction catheter was quickly advanced through the patient’s tracheotomy tube into the trachea to induce a cough. The CPFR was measured by using the Electronic Peak Flow Meter and was recorded. With 2 minutes of rest between attempts, the highest flow rate generated during 3 coughs was recorded as the patient’s CPFR and was used for data analysis. Figure 2 is a flow chart of the study design.

The decision on tracheotomy tube decannulation was made by the unit’s physiotherapists and doctors who did not know the measurement data. No attempt was made to decannulate patients considered unsuitable for decannulation on clinical grounds (poor GCS score, multiorgan comorbid disease, multiorgan failure). These patients were considered certain to have an unsuccessful decannulation attempt and were included in the unsuitable for decannulation group. Decannulation outcome was considered successful if the patient did not require reinsertion of the tracheotomy tube within 72 hours.10,11,18

**Statistical Analysis**

Univariate logistic regression was used to identify independent predictors for successful decannulation. Effects of the variables found significant were subsequently subjected to multivariate logistic regression. The backward likelihood method was used to determine the variables included in the final model. Results of prediction were expressed as odds ratios and 95% confidence intervals. A receiver operating characteristic
with unsuccessful decannulation. The crude odds ratio from univariate logistic modeling for each variable as possible predictors of decannulation outcome is displayed in Table 3. CPFR was significantly correlated (ROC) curve with different thresholds was constructed to determine the optimal cutoff value for the independent predictor identified. A P value of .05 or less was used to indicate statistical significance.

Results

A total of 32 patients were recruited to participate in the study. Demographic characteristics and reasons for admission are summarized in Table 2. Mean duration of mechanical ventilation was 13.2 days, and mean duration of breathing spontaneously with a tracheotomy tube was 8.8 days. Among the 32 patients enrolled in the study, attempts at decannulation were made in only 23. Attempts were successful in 21 (66%), and reinsertion of the tracheotomy tube was required in 2 (6%). The remaining 9 patients (28%) were considered clinically unsuitable for decannulation and were transferred to a convalescent hospital for long-term care with their tracheotomy tube in place. Reevaluation for decannulation would be undertaken at a later stage when the patients’ condition improved. The mean length of the tracheotomy tube used in the group with successful decannulation was 7.14 (SD, 0.4) cm and that for the group with unsuccessful decannulation was 7.07 (SD, 0.57) cm. The length of the tubes used did not differ between these groups (P = .69).

The mean peak flow rate recorded in the successful decannulation group (n = 21) was 42.62 L/min (SD, 12.6), which was significantly higher than that (29.91 L/min; SD, 11.0) in the unsuccessful decannulation group (n = 11; P = .009). Histogram of the CPFR of these patients are displayed in Figure 3. Mean GCS scores were 9.81 (SD, 1.7) for patients with successful decannulation and 8.2 (SD, 2.7) for patients with unsuccessful decannulation. The crude odds ratio from univariate logistic modeling for each variable as possible predictors of decannulation outcome is displayed in Table 3. CPFR was significantly correlated

### Table 2

<table>
<thead>
<tr>
<th>Demographics of the 32 patients</th>
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<tbody>
<tr>
<td>Sex, No. (%) of patients</td>
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<tr>
<td>Male</td>
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<tr>
<td>Female</td>
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<td>Age, y</td>
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<tr>
<td>Mean (SD)</td>
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<td>Median (range)</td>
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<tr>
<td>Reasons for neurosurgical admission, No. (%) of patients</td>
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<tr>
<td>Head injury</td>
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<tr>
<td>Intracerebral hemorrhage</td>
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<tr>
<td>Subarachnoid hemorrhage with ruptured arteriovenous malformation or aneurysm</td>
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<tr>
<td>Brain tumor</td>
</tr>
<tr>
<td>Subdural hemorrhage</td>
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<tr>
<td>Hydrocephalus</td>
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<tr>
<td>No. of previous operations performed</td>
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<tr>
<td>Mean (SD)</td>
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<td>Median (range)</td>
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<tr>
<td>Total duration of mechanical ventilation, d</td>
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<td>Mean (SD)</td>
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<td>Median (range)</td>
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<tr>
<td>Ventilation days before tracheotomy</td>
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<tr>
<td>Mean (SD)</td>
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<td>Median (range)</td>
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<tr>
<td>Duration of spontaneous breathing with tracheotomy tube, d</td>
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<td>Mean (SD)</td>
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<tr>
<td>Median (range)</td>
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<tr>
<td>Inner diameter of tracheotomy tube, mm</td>
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<tr>
<td>Mean (SD)</td>
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<tr>
<td>Median (range)</td>
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</table>

**Figure 3** Histograms of peak flow rate after induced cough in patients with unsuccessful or successful decannulation.
was drawn with different thresholds for CPFR in predicting decannulation outcome (Figure 4). The area under the ROC curve was 0.814. The ROC curve suggested that a CPFR threshold of 29 L/min was the optimal cutoff point.

**Discussion**

This study confirms that cough strength, as measured by CPFR, is a useful predictor of successful tracheotomy tube decannulation in neurosurgical patients. The accuracy of predicting successful decannulation on the basis of CPFR was 75%. This outcome is considered satisfactory, because only 2 patients required reintubation and those patients who were not recommended for decannulation were transferred to a convalescent hospital and were reevaluated at a later date.

Predictors of successful decannulation include level of consciousness, secretions, oxygenation,19 and the ability to produce a vigorous cough.20 Irrespective of the method used to measure cough strength, a consistent association between cough and extubation/decannulation outcomes has been reported.10-12,14,18 In our study, we used an objective, inexpensive, and reproducible measure of "unassisted" reflex cough strength obtained via a peak flow meter. The use of a peak flow meter for measurement of CPFR has been reported in extubation outcome studies,11,18 but in only a single study14 did investigators report its use in research on decannulation outcomes.

In the study by Bach and Saporito,14 CPFR was measured in 49 tracheostomized patients with chronic respiratory failure due to neuromuscular disease. The results showed that a CPFR of 160 L/min after decannulation demarcated success from no success. We found that the optimal cutoff value for CPFR in predicting successful decannulation in our neurosurgical cohort was only 29 L/min. Direct comparison of Bach and Saporito’s study with our study was not deemed appropriate because, in our study, CPFR was due to the intrathoracic pressure generated by a cough reflex induced by artificial stimulation of the airway with the tip of a suction catheter. In Bach and Saporito’s study, the CPFR was a result of maximal insufflation (by an In-Exsufflator) followed by expiratory flow enhancement by means of an external abdominal thrust. In other words, the patients’ lungs were passively and maximally inflated by a machine, a maneuver that would facilitate a more forceful expiratory recoil in any event, and the actual expiration was further enhanced by a manual compressive external abdominal thrust. This difference in procedure explains the much

with decannulation outcome \((P = .02)\). Neither volume of tracheal secretions \((P = .65)\) nor GCS score \((P = .06)\) showed a significant correlation with decannulation outcome. GCS score and CPFR were selected as potential predictors for further multivariate regression analysis because the correlation between GCS score and decannulation outcome appeared to be almost significant \((P = .06)\).

The result of the multivariate model revealed that CPFR was the only significant predictor for successful decannulation. The odds of having a successful decannulation was 11.8% for each CPFR increment. The overall accuracy of prediction for both successful and unsuccessful cases was 75%. The positive predictive value was 78.3%. Among the 21 patients with successful decannulation, the results of attempted decannulation were correctly predicted in 18, giving a sensitivity of 85.7%. Of the 11 unsuccessful decannulations, 6 were predicted, resulting in a specificity of 54.5%. An ROC curve

#### Table 3

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Crude odds ratio (95% CI)</th>
<th>(P)</th>
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<tbody>
<tr>
<td>Score on Glasgow Coma Scale</td>
<td>1.41 (0.98-2.01)</td>
<td>.06</td>
</tr>
<tr>
<td>Peak flow rate during induced cough</td>
<td>1.12 (1.02-1.23)</td>
<td>.02</td>
</tr>
<tr>
<td>Volume of tracheal secretions</td>
<td>0.97 (0.84-1.12)</td>
<td>.65</td>
</tr>
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</table>

Abbreviation: CI, confidence interval.
higher expiratory flow rates in Bach and Saporito’s study compared with the flow rates recorded in our study. Furthermore, the air leak around the noncuffed tracheotomy tube in our cohort further reduced the expiratory flow recorded through the tracheotomy tube.

A CPFR of 60 L/min was reported in the studies by Smina et al\textsuperscript{18} and Salam et al.\textsuperscript{11} The CPFR was again higher than that produced by our patient cohort, but in their studies\textsuperscript{11,18} CPFR was generated from a voluntary cough through a cuffed tracheal tube, and, although they were critically ill, patients in their studies did not have a neurological disorder. The neurological status of a patient can influence cough strength because of a reduced neuromuscular effect on intrathoracic pressure.\textsuperscript{11}

An induced CPFR of 29 L/min or greater was associated with a high chance (85.7\%) of successful extubation. Of the 11 unsuccessful decannulation cases, in only 2 cases was the patient actually decannulated and then required reintubation; the other 9 cases involved patients considered inappropriate for a decannulation attempt. A clinical decision not to decannulate was taken by the unit’s physiotherapist or the doctor in charge on the basis of a patient’s GCS score and comorbid diseases. No objective guideline was adopted. These 9 patients all were transferred to convalescent hospitals with the tracheotomy tube in place. The number of actual unsuccessful decannulations would most likely have been higher if decannulation had been attempted in these 9 patients, but doing so would have reflected poor clinical judgment and unethical practice.

Unlike other investigators,\textsuperscript{10,13} we did not find that volume of tracheal secretions or GCS score was associated with decannulation outcomes. In 3 other studies,\textsuperscript{10,11,18} researchers used different methods of measurement of tracheal secretion volumes to determine the role of those volumes as predictors of extubation outcomes in critically ill patients. Although Khamiees et al\textsuperscript{10} found a positive correlation between extubation outcome and secretion volume, secretion measurement was only subjective. Smina et al\textsuperscript{18} used a suction trap and collected secretions from 2 to 6 hours before extubation but found no relationship between volume of secretions and extubation outcome. Salam et al\textsuperscript{11} adopted frequent suctioning during the 2 hours preceding extubation and found that patients who generated more than 2.5 mL/h of secretions had a higher risk of unsuccessful extubation. The different methods of measurement, the variations in the actual amount of secretions produced, and the different characteristics of the patients in the different studies all may have contributed to the different study outcomes.

All of our patients had undergone neurosurgical procedures; none had a respiratory infection develop and none had sputum retention. The amount of sputum collected from patients in our study was actually small. The effect of such a small amount of secretions would not have been sufficient to influence the outcome of decannulation. With recent improvements in nursing care and advances in antibiotics, pulmonary secretions are now an infrequent problem for most patients after neurosurgery.

The GCS score is a measure of neurological status that could influence CPFR, but it was not a potential predictor of successful decannulation. Published reports of the predictive power of neurological status on extubation outcome are conflicting. Although successful extubation attempts are associated with a higher GCS score in patients after neurosurgery,\textsuperscript{11,13} a significant relationship between poor GCS scores and rate of reintubation was not found.\textsuperscript{12} Our findings are similar to those of Koh et al\textsuperscript{1} and Coplin et al\textsuperscript{2}; the GCS score had borderline predictive power for extubation or decannulation outcomes but was not statistically significant.

**Limitations of the Study**

Most of our patients had a noncuffed tracheotomy tube, and air leakage during CPFR measurement was unavoidable. To ensure standardization, we deflated the cuffs of the cuffed tracheotomy tubes during the measurement procedure.

The size of the tracheotomy tube can affect expiratory flow.\textsuperscript{21} Although we adopted a standard length of suction catheter to provoke cough, the varied lengths of the tracheal tubes would potentially allow some variation in the strength of the stimulus. We do not consider this variation important, however, because the size and length of the tubes used did not differ between groups. We did not study how the diameter of the tube might affect the peak cough rate. A smaller tube might allow more air to leak around the tube, resulting in a lower recorded CPFR. However, the mean sizes of the tubes used in both groups were similar. Furthermore, because the CPFR was relatively low at only about 30 L/min, the size of the tracheotomy tube most likely would not have a major effect.

**Induced CPFR was a good predictor of successful decannulation of tracheotomy tubes in neurosurgical patients.**

**The optimal cutoff value for CPFR in predicting successful decannulation in our neurosurgical cohort was only 29 L/min.**
The number of “true” unsuccessful decannulations was small. Thus, our suggestion that a CPRF of less than 29 L/min would allow precise prediction of unsuccessful extubation may not be truly accurate. This small number may also make the discriminative usefulness of the optimal cutoff value of CPRF (29 L/min) less powerful. However, as previously explained, a large number of unsuccessful decannulations would reflect poor clinical decision making, and a study design that allowed a large number of true unsuccessful cases (which consequently would lead to reintubation) would violate essential ethical considerations. Nevertheless, we found a satisfactory positive predictive value of 85.7%, and the suggested cutoff will enhance appropriate clinical decisions in the group of patients in whom the chance of unsuccessful decannulation is considered a clinically acceptable risk.

Conclusion

Induced CPRF was a good predictor of successful decannulation of tracheotomy tubes in neurosurgical patients. A CPRF of 29 L/min may be considered as the determinant point. The use of the portable Piko-I electronic peak flow meter with our induced cough method provides a simple, inexpensive, and objective adjunctive measurement of cough strength to determine the best time for tracheotomy decannulation. The use of CPRF for predicting successful tracheotomy decannulation in other populations of patients should be explored further.

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FINANCIAL DISCLOSURES

None reported.

eLetters

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