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# Extubation Outcome using Cough Expiratory Flow in Surgical Patients: An Observational Study

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## Abstract

**Background:** Reintubation following a successful weaning seems to be an unavoidable event, even in well run intensive care units. The hospital mortality rate for these patients increases substantially. Reducing reintubation rate is of utmost importance for improved outcome.

**Method:** We conducted a one-year prospective observational study of adult post-surgical patients admitted to the surgical intensive care unit and mechanically ventilated for more than 24 hours. Forced cough peak expiratory flow (FCPEF) was assessed by using a digital peak flow meter placed in-line with the endotracheal before extubation after passing previously a spontaneous breathing trial.

**Results:** One hundred and one patients were enrolled. There were 71 male patients (70.3%). The median age was 69 ± 14.14 year-old. Eighty-four patients (83.2%) were intubated during a surgical procedure and then transferred to the surgical intensive care unit for hemodynamic monitoring. The median mechanical ventilation time before extubation was 4 ± 3.7 days. The median forced cough peak expiratory flow was 29 ± 21.44 L/min for the entire cohort. The median forced cough peak expiratory flow was 3.30 ± 26.61 L/min for the failed extubation group, and 30.15 ± 20.74 L/min for the successful extubation group ($p = 0.21$). Logistic regression revealed that failed extubation was strongly associated with ICU stay ($p < 0.001$; OR 1.21, 95% CI 1.09-1.34) and mortality ($p = 0.014$; OR 8.92, 95% CI 1.56-50.96).

**Conclusion:** In this series of surgical patients, measurement of forced cough peak expiratory flow does not bring additional value compared to the traditional extubation parameters.

## Keywords

Mechanical ventilation, Forced cough expiratory flow, Extubation, Reintubation

## Introduction

Mechanical ventilator management is part of daily activity in any modern intensive care unit, and endotracheal tube is the main route used to provide secure airway. After stabilization of the medical or surgical condition resulting in respiratory failure, early assessment of readiness for weaning is recommended [1]. Intubated patients usually go through a spontaneous breathing trial for the assessment of readiness before extubation. Nevertheless, there are still a considerable percentage of planned extubation patients who are re-intubated after passing this trial [2,3]. Reducing reintubation is of utmost importance for improved clinical outcome. Pain is an adverse factor for weaning and extubation. Pain elicited from tubes and catheters are common in surgical and medical patients in the ICU; however the surgical cohort presents an additional pain source, the incisional pain, that it is not present in medical patients. The most important procedure-related predictor of pulmonary risk is surgical site. It is well known that upper abdominal and thoracic surgery carried the greatest risks [4]. The type of procedure and location of the incision could have detrimental effect on different component of lung volume and cough strength [5-8]. Incisional pain could hamper the ability to produce an effective voluntary cough. Cough strength, a surrogate of airway patency, can be represented by the voluntary forced cough peak expiratory flow (FCPEF). This could be easily measured even in intubated patients, using a digital peak-flow meter. Voluntary forced cough peak expiratory flow to predict extubation outcome have been previously reported in the medical and mixed ICU patients [9-11]. However, the utility of voluntary forced cough peak expiratory flow in surgically patient has been poorly evaluated. In this observational non-intervention study we evaluate the voluntary forced cough peak expiratory flow on the outcome of extubation in surgical patients who had passed a spontaneous breathing trial.

## Material and Method

This study was approved by the Investigation and Research Board of Chang Gung Memorial Hospital. The annual admission rate in our unit is around 300 admissions per year. For a 95% confidence level and a confidence interval of 8, the sample size needed was calculated at 100. From June 2012 to July 2013, a convenience sample of consecutive admitted patients to the surgical intensive care unit of Chang Gung Memorial Hospital at Chia-Yi, were included. Patients should be ventilated for more than 24 hours, older than 18 year old and able to obey command and to perform voluntary cough. Patients with the

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following conditions were excluded: prolonged weaning [1] (patients who require more than three SBT or over 7 days of weaning after the first SBT), ventilated through tracheostomy tube, neurologic impairment to perform voluntary cough, neuromuscular dystrophy, or pregnant. Informed consent was obtained from the patient and/or the nearest relatives before inclusion. All endotracheal tubes in our unit were secure using adhesive type, Lillehei method [12,13]. Readiness for extubation is assessed on a daily basis. Those patients whose hemodynamic parameters are stable without vasopressor support, PaO2/FI O2 ratio > 200, positive end-expiratory pressure ≤ 8 cm H20, and pain visual analog scale ≤ 5 (10 for maximal pain-0 for no pain) were assessed for spontaneous breathing trial (SBT). The SBT was carried out for 30 minutes using a T-piece or low level pressure support ≤ 8 cm H20 at the preference of the attending surgeon. If the patient develops sustained pulse rate increases or decreases > 20 beats per minute, systolic blood pressure increases or decreases > 20 mmHg, breath rate > 35/min, arterial saturation < 90%, new onset sustained arrhythmia, respiratory distress (paradoxical breath or accessory muscles use), sustained agitation, diaphoresis, or anxiety despite reassurance by nursing staff and respiratory therapist; it was considered a failed SBT.

## Protocol

After a successful SBT, the patient is judged ready for extubation, and forced cough peak expiratory flow (FCPEF) is assessed. The forced cough peak expiratory flow is assessed by the intensive care unit respiratory therapy by using a digital peak flow meter (HT-801A Hometech, Taiwan) placed in-line with the endotracheal. The patient is placed in sitting position. After a short rapid expiration followed by maximal inspiration, the patient is instructed to "cough" maximally through the mouth piece. Three series of forced cough peak expiratory flow are recorded given to a mean and a highest value. The result of FCPEF was blinded to the primary care physician. Patient who did not required re-intubation within 48 hours was considered a successful extubation. The decision to re-intubate was in accordance to the clinical condition of the patient, and sorely at the discretion of the attending physician. Patients were followed until discharge from hospital or death.

## Data Collection

The following clinical data was collected for every patient: age, sex, surgical procedure type, indication for intubation, ICU admission's APACHE (Acute Physiology And Chronic Health Evaluation) II score, SAPS (Simplified Acute Physiology Score) II score, duration of mechanical ventilation, hemoglobin/hematocrit level, forced cough expiratory flow, arterial and central venous blood gas analysis, and cardiorespiratory variables after 30 minutes of SBT. Post extubation ICU and hospital stay as well as clinical outcome were recorded.

## Statistical Analysis

Differences in proportions were compared using Chi-Square or Fisher exact test depending on cell size. Mann-Whitney U test was used for statistical analysis of non-parametric value. All p-values were two sided, and the level of significance was set at 5%. Binominal logistic regression analysis was used to evaluate the effect of failed extubation on ICU stay and mortality. The clinical data was analyzed using SPSS software (SPSS Inc, Chicago, Illinois).

## Results

From June 2012 to June 2013, 101 patients admitted to the surgical intensive care of Chang Gung Memorial hospital at Chia-Yi with mechanical ventilator support greater than 48 hours. All patients received surgical intervention under general anesthesia during the same admission. There were 71 male patients (70.3%). The median age was 69-year-old. Eighty-four patients (83.2%) were intubated during a surgical procedure and then transferred to the surgical intensive care unit for hemodynamic monitoring; sixteen patients were intubated because of respiratory failure at ward and then transfer to the ICU, and one patient had a previous failed extubation in the ICU. The median APACHE II score and SAPS II score on admission were 19 and 52 respectively (Table 1). The mean mechanical ventilation time before extubation was 4 days (range 2-21 days). Blood analysis result is presented in table 2. Spontaneous breathing trial through pressure support ventilation was used in 97 patients (96%). The

**Table 1:** Patient characteristics. RSBI: rapid shallow breath index; PiMax: maximal inspiratory pressure; VT: tidal volume; ICU: intensive care unit.

| Patient Characteristics | | | |
|---|---|---|---|
| All Patients (n = 101) | Successful Extubation (n = 90) | Failed Extubation (n = 11) | p value |
| Median ± SD | Median ± SD | Median ± SD | |
| Age (years) | 69 ± 14.14 | 68 ± 14.50 | 72 ± 10.82 | 0.56 |
| BMI | 23.33 ± 3.33 | 23.31 ± 3.47 | 23.7 ± 1.81 | 0.87 |
| APACHE II Score | 19 ± 7.73 | 18.5 ± 7.89 | 22 ± 6.44 | 0.49 |
| SAPS II score | 52 ± 12.02 | 52 ± 12.32 | 52 ± 8.48 | 0.36 |
| Mechanical Ventilation (days) | 4 ± 3.70 | 4 ± 3.43 | 5 ± 5.4 | 0.14 |
| Pulse Rate (min) | 88 ± 19.75 | 88 ± 9.48 | 89 ± 18.9 | 0.68 |
| Breath Rate (min) | 22 ± 5.53 | 21.5 ± 5.39 | 24 ± 6.73 | 0.31 |
| RSBI | 54 ± 25 | 56.5 ± 23.94 | 47 ± 33.33 | 0.27 |
| PiMax (-) | 30 ± 9.98 | 30 ± 10.00 | 36 ± 10.09 | 0.59 |
| VT (ml) | 389 ± 172.02 | 382.50 ± 175.22 | 459 ± 149.81 | 0.58 |
| Hemoglobin (g/dL) | 10.7 ± 1.74 | 10.9 ± 1.75 | 9.1 ± 1.10 | 0.002 |
| Hematocrit (%) | 32.10 ± 5.06 | 32.7 ± 5.05 | 28.1 ± 2.95 | 0.001 |
| ICU stay (days) | 7 ± 7.04 | 6 ± 5.52 | 22 ± 7.78 | < 0.001 |

**Table 2:** Blood gas analysis.

| Blood Gas Analysis | | | | | |
|---|---|---|---|---|---|
| | | All Patients (n = 101) | Successful Extubation (n = 90) | Failed Extubation (n = 11) | p value |
| | | Median ± SD | Median ± SD | Median ± SD | |
| Arterial | PCO2 (mmHg) | 37.20 ± 5.57 | 36.8 ± 5.58 | 40 ± 5.49 | 0.21 |
| | PO2 (mmHg) | 117.80 ± 29.26 | 117.65 ± 29.69 | 121.90 ± 26.54 | 0.61 |
| | HCO3 (mm/L) | 25.70 ± 3.56 | 25.70 ± 3.47 | 26.00 ± 4.36 | 0.57 |
| | PA-a O2 (mmHg) | 91.50 ± 36.69 | 95.75 ± 34.26 | 84.80 ± 54.93 | 0.61 |
| | O2 Sat (%) | 98.50 ± 0.69 | 98.50 ± 0.69 | 98.60 ± 0.69 | 0.57 |
| Venous | PCO2 (mmHg) | 45.10 ± 5.81 | 45.10 ± 5.74 | 48.60 ± 6.54 | 0.25 |
| | PO2 (mmHg) | 38.80 ± 6.73 | 38.8 ± 6.09 | 49.30 ± 10.71 | 0.61 |
| | HCO3 (mm/L) | 28.30 ± 3.91 | 28.30 ± 3.90 | 27.00 ± 4.26 | 0.98 |
| | PA-a O2 (mmHg) | 156.07 ± 21.03 | 157.85 ± 20.29 | 152.30 ± 26.82 | 0.23 |
| | O2 Sat (%) | 73.90 ± 7.51 | 73.95 ± 7.23 | 73.60 ± 9.86 | 0.92 |

**Table 3:** Forced cough expiratory flow results. Mean and highest record: mean and highest value of the three series of forced cough peak expiratory flow before extubation.

| Cough Expiratory Flow | | | | |
|---|---|---|---|---|
| | **All Patients** | **Successful Extubation (n = 90)** | **Failed Extubation (n = 11)** | **P Value** |
| | Median (L/min) ± SD | Median (L/min) ± SD | Median (L/min) ± SD | |
| Mean Record | 29 ± 21.44 | 30.15 ± 20.74 | 3.30 ± 26.61 | 0.21 |
| Highest Record | 33 ± 24.28 | 33 ± 23.73 | 10 ± 29.49 | 0.55 |

mean and highest FCPEF for the entire cohort was 29.0 L/min and 33 L/min (Table 3). Although the mean and highest recorded FCPEF was higher for patient successfully extubated compared to the failed extubation group, it did not reach statistical significance ($p = 0.21$). Thirty-one patients had mean FCEF of less than 10 L/min (74% were cardiothoracic patients). There were 11 episodes of re-intubations, 10.9%. The median ICU stay for the entire cohort was 7 days. Patients with failed extubation had a mean ICU stay of 22 days, while patients who were successfully extubated had an ICU stay of 6 days, ($p < 0.001$). The overall mortality was 12.9% (n =13). Logistic regression revealed that failed extubation was strongly associated with ICU stay ($p < 0.001$; OR 1.21, 95% CI 1.09-1.34) and mortality ($p = 0.014$; OR 8.92, 95% CI 1.56-50.96).

## Discussion

Surgical patients are usually admitted to the ICUs for hemodynamic monitoring following major surgery, and less frequently for the management of surgical complications. Since the major indication for mechanical ventilation is not respiratory failure, these patients are usually extubated soon following a fast tract protocol. Surgical incisional pain is a particular problem in the surgical cohort with detrimental effect on lung expansion [14]. Previous studies had already addressed the effect of different surgical procedure on lung volume [6-8,14-16].

Voluntary forced cough peak expiratory flow to predict extubation outcome have been previously reported [9-11,17,18]. However, the recommended cut off value to predict extubation failure varies from 35 L/min [17] to 60 L/min [9-11,18]. According to Beuret, et al. [17], patients with a FCPEF of ≦ 35 L/min presents with 24% risk of extubation failure while others had reported that patients with FCPEF of ≦ 60 L/min have five time as likely of a failed extubation [9-11,18]. This discrepancy in the threshold value may possibly be explained by the different method and device used for measurement. Bongers, et al. had reported previously that peak flow measurements are affected by the instruction given and by the device and peak flow scale used [18]. In our surgical cohort, the median voluntary forced cough peak expiratory flow for "successful extubation" group was 29 ± 21.44 L/min, and for the "failed extubation" group was 3.30 ± 26.61 /min, ($p = 0.21$). Thirty-one patients of our cohort had FCPEF of less than 10L/min (74% were cardiothoracic patients). This lower value of forced cough expiratory flow may be a consequence of sternotomy or thoracotomy wound pain over a normal cough mechanism that is not present in non-surgical patients. Thoracic pain following open heart surgery during different cough condition increases by 30% from baseline pain during the first two days [19,20].

The major limitations of this report are the observation study design and the small number of patients. In this study, the only intervention was the measurement of voluntary forced cough peak expiratory flow. Other parameters such the weaning preference (pressure support or T-piece) and pain medications used by each attending surgeon were not interfered. Although the pain control protocol used by different surgeons of different specialty was not uniform and difficult to evaluate, all patients has a pain visual analog scale of ≤ 5 before assessing for SBT. The effect of different pain medication over extubation outcome merits further investigation. Despite this report's limitations, from its prospective design and focusing solely in surgical patients, it still brings some insight into some of the most cumbersome and unavoidable problem in any modern ICU, the failed extubation.

## Conclusion

We evaluate forced cough expiratory flow in surgical patients in combination of traditional weaning parameters. Unfortunately, in our surgical cohort, forced cough expiratory flow was not predictive for extubation failure after passing a successful spontaneous breathing trial.


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## Competing Interest

The authors declare that they have no competing interest.

## Author's Contributions

M-S Lu: Study design, data acquisition, analysis and interpretation, literature review and manuscript drafting.

T-M Yang: study design, analysis and interpretation and critical review.

C-C Chang: analysis and interpretation, and critical review.

C-C Lin: data acquisition and literature review.

Y-K Huang: data acquisition and literature review.

Y-H Tsai: study design, analysis and interpretation, critical review and manuscript drafting.

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