

Flow versus pressure triggering in mechanically ventilated acute respiratory failure patients

Magdy M. Khalil^a, Nevine M. Elfattah^a, Mohsen M. El-Shafey^b,
Nermine M. Riad^a, Raed A. Aid^b, Alaa M. Anany^c

Background The effects of flow triggering (FT) compared with pressure triggering (PT) on breathing effort have been the focus of several studies, and discrepant results have been reported; yet, it remains an area of conflict that warrants further studies.

Objective The aim of this work is to compare flow versus PT in ventilating patients with acute respiratory failure.

Patients and methods One hundred patients with acute respiratory failure of pulmonary origin were assigned randomly to two groups: 50 patients ventilated with PT and 50 patients ventilated with FT. The primary end points were weaning duration, evaluation of patient/machine synchronization, total duration of ventilation and ICU stay as well time under sedation and occurrence of complications. Mortality was considered the secondary end point. Patients were categorized into those with obstructive, restrictive, and combined pulmonary disease according to their medical history, and clinical and radiological assessment, and also more and less severe disease according to the APACHE II score level (cut-off point).

Results In all the patients studied, including those with restrictive pulmonary disorder and more severe disease (APACHE II score ≥ 32.5), there was a statistically significantly shorter duration of weaning, duration of ventilation, and duration of ICU stay in the FT group than the PT group. The pre-extubation oxygenation index was highly statistically significantly better in the FT group than

the PT group ($P < 0.001$). In patients with obstructive pulmonary disorders, combined pulmonary disorders, and less severe disease (APACHE II < 32.5), there was no significant difference between both PT and FT groups in these parameters.

Conclusion FT may be considered to be better than PT in ventilating acute respiratory failure patients with a restrictive pattern and those with higher severity scoring. In obstructive and mixed ventilatory impairment, use of either of them does not make a difference. *Egypt J Broncho* 2015 9:198–210

© 2015 Egyptian Journal of Bronchology.

Egyptian Journal of Bronchology 2015 9:198–210

Keywords: mechanical ventilation, respiratory failure, triggering

Key messages

- (1) Which is better: Flow or Pressure Triggering in Mechanically Ventilated Acute Respiratory Failure Patients?
- (2) Is there a difference in obstructive, restrictive or combined Respiratory Failure Patients?
- (3) How do Flow or Pressure Triggering in Mechanically Ventilated Acute Respiratory Failure Patients affect the outcome?

^aDepartment of Chest Diseases, Ain Shams University, Cairo,

^bDepartment of Chest Disease, Mansoura University, Mansoura,

^cMinistry of Health, Cairo, Egypt

Correspondence to Nevine M. Abd Elfattah, MD, PhD, 8 Ossman Abdel Hafeez, Nasr City, Cairo 11371, Egypt
Tel: +20 122 312 8770; fax: +224010321;
e-mail: nfattah@hotmail.com

Received 22 April 2015 **Accepted** 26 April 2015

Introduction

Respiratory failure is a syndrome in which the respiratory system fails in one or both of its gas-exchanging functions — that is, oxygenation of, and carbon dioxide elimination from, mixed venous (pulmonary arterial) blood [1].

Acute respiratory failure is characterized by an inability to maintain adequate oxygenation (a PaO_2 of < 50 – 55 mmHg or an arterial oxygen saturation by pulse oxymetry of $< 85\%$ on room air), ventilation (a $\text{PaCO}_2 > 50$ mmHg or increase of > 10 mmHg over the base line PaCO_2), or both, which develops over a short period of time. For practical purposes, the onset usually occurs over several hours or days [2].

Acute respiratory failure can be classified into hypercapnic or hypoxemic respiratory failure, and can

also be divided into those with normal versus abnormal chest radiography [2].

There are three locked steps to the diagnosis of ARF:

- (a) The clinical suspicion that ARF might be present,
- (b) Confirmation by arterial blood gas analysis that ARF is present, and
- (c) Further diagnostic steps that identify the specific etiology of the ARF [3].

One of the most serious complications of ARF is nosocomial pneumonia, usually caused by virulent organisms, frequently Gram-negative bacilli that cause necrotizing pneumonia, and may be resistant to common antibiotics. Acute stress ulceration with resultant upper gastrointestinal bleeding is a well-recognized complication in patients with respiratory failure [4].

Pulmonary embolism is a frequent finding in critically ill patients with ARF. When ARF and acute renal failure occur concurrently in critically ill patients, each condition may worsen or precipitate the other [5].

When correcting hypoxemia, the clinician must also address any coexisting hypercapnia and respiratory acidosis, and the immediacy of correction depends on the magnitude of the acidosis and its attendant effects [1].

When adequate oxygenation cannot be maintained by noninvasive means or if progressive hypoventilation and hypercapnia with respiratory acidosis occurs, endotracheal intubation and mechanical ventilatory support should be initiated. Mechanical ventilation can produce positive pressure at the airway opening or create negative pressure around the chest wall. Use of negative pressure ventilation is generally restricted to patients with chronic neuromuscular weakness or chest wall deformity [6].

For air to enter the lungs, a pressure gradient must exist between the airway and alveoli. This can be accomplished either by increasing pressure at the airway (positive-pressure ventilation) or by lowering pressure at the level of the alveolus (negative-pressure ventilation). Positive-pressure ventilation can be achieved by an endotracheal or a tracheostomy tube or noninvasively through a nasal mask or a facemask. In the past, this was invariably performed using an endotracheal or a tracheostomy tube, but in recent years, there has been an increasing trend toward the use of noninvasive ventilation, which can be accomplished using either a full face mask (covering both the nose and the mouth) or a nasal mask [7].

In acute care settings, critical care ventilators or portable positive-pressure devices are used in volume-limited or pressure-limited modes. Although either mode can be used with the expectation of similar rates of success, pressure-limited modes appear to be more readily accepted by patients. In the acute setting, nasal or oronasal masks are most commonly used [8].

In 1994, Tobin [9] listed the objectives of mechanical ventilation as follows:

- (1) Improve pulmonary gas exchange:
 - (a) Reverse hypoxemia.
 - (b) Relieve acute respiratory acidosis.
- (2) Relieve respiratory distress:
 - (a) Decrease oxygen cost of breathing.
 - (b) Reverse respiratory muscle fatigue.

- (3) Alter pressure–volume relationship:
 - (a) Reverse or prevent atelectasis.
 - (b) Improve lung compliance.
 - (c) Prevent further lung injury.
- (4) Permit lung and airway healing.

Selection of the initial ventilator setting is performed on the basis of the patient's size and clinical condition. Settings are entered and the proper function of the ventilator is verified before connection to the patient. Ventilatory settings must be repeatedly reviewed to optimize ventilatory support while minimizing risks [10].

After initiating ventilatory support, the clinician should 'fine-tune' the trigger sensitivity setting. Fine-tuning is necessary because too sensitive a setting can cause some ventilators to autotrigger whereas an unresponsive trigger level can add to the breathing work load and cause patient–ventilator asynchrony [11].

Triggering refers to the mechanism through which the ventilator senses inspiratory effort and delivers gas flow or a machine breath in concert with the patient's inspiratory effort. In modern ventilators, the demand valve is triggered by either a fall in pressure (pressure trigger) or a change in flow (flow trigger). With pressure-triggered ventilation, a preset pressure sensitivity has to be achieved before the ventilator delivers fresh gas into the inspiratory circuit; with flow-triggered ventilation, a preset flow sensitivity is used as the trigger mechanism [12].

The most common trigger variables are time (the ventilator initiates a breath according to asset frequency, independent of the patient's spontaneous efforts), pressure (the ventilator senses the patient's inspiratory effort in the form of a decrease in baseline pressure and starts inspiration independent of the set frequency), and flow (the ventilator senses the patient's inspiratory effort as a decrease in the baseline flow through the patient circuit or senses inspiratory flow directly with a sensor at the patient's airway opening) [13].

Pressure triggering (PT) is the oldest and simplest technique for the detection of patient effort. The sensitivity or trigger threshold is set in centimeters of H_2O relative to the baseline pressure.

As an example, if baseline pressure is 5 cmH_2O and the trigger threshold is 2 cmH_2O , when patient effort causes pressure in the circuit to decrease to 3 cmH_2O , the breath is triggered and if the baseline pressure is changed, for instance to 10 cmH_2O and the trigger threshold remains the same (2 cmH_2O), the ventilator is triggered when circuit pressure decreases to less than

8 cmH₂O; the ability to maintain the trigger threshold constant irrespective of alterations of baseline pressure is frequently referred to as 'positive end expiratory pressure' (PEEP) compensation [14].

Flow triggering (FT) was introduced by Engstrom in the early 1980s, but did not become popular until it was reintroduced by Puritan Bennett in 1988; since then, FT has become standard on current ventilators. Like so much of ventilator technology, the methods of FT vary from manufacturer to manufacturer. FT systems vary in placement of the flow transducer, presence and absence of a continuous flow, and the ability to adjust bias flow and flow sensitivity [15].

FT is implemented using one of three methods; the first simply measures a change of flow caused by the patient's inspiratory effort, there is no continuous flow in the circuit, and at end-expiration flow is 0. The second provides a preset non adjustable level of continuous flow in the circuit, from which a change of flow (the flow sensitivity) is detected. The third enables the clinicians to set the continuous flow and the flow sensitivity. In this case, a change in flow through the circuit caused by the patient's inspiratory effort reduces the flow below the flow trigger threshold setting and a breath is triggered. In the presence of a leak, this system can be tailored to overcome the leak while maintaining appropriate triggering [16].

FT reduces inspiratory effort during weaning from mechanical ventilation. There was no change in breathing pattern, minute ventilation, and lung mechanics, and the magnitude of the inspiratory effort decreased significantly with FT compared with PT in both instances [17].

The aim of this work is to compare flow versus PT in ventilating patients with acute respiratory failure.

Patients and methods

This study was carried out in the Respiratory Intensive Care Unit of Thoracic Medicine Department, Mansoura University Hospital, during the period from July 2011 to August 2013, after fulfillment of departmental ethical committee requirements and obtaining oral consent from the patients or their surrogate.

Study design

This is a prospective clinical trial in which one hundred patients with acute respiratory failure of pulmonary origin were assigned randomly to two groups: group I included 50 patients who were ventilated through PT and group II included 50 patients who were ventilated through FT. The primary end points were weaning

duration, patient/machine synchronization, total duration of ventilation, ICU length of stay, time under sedation, and occurrence of complications. Mortality was considered the secondary end point.

Patients

Inclusion criteria

Patients with acute respiratory failure (either *de novo* or on top of chronic) because of pulmonary causes and indicated for invasive mechanical ventilation were included in this study. Respiratory failure was defined as a PaO₂ measured at sea level of less than 8 kPa (60 mmHg) or PaCO₂ above 6.5 kPa (49 mmHg) [18].

Exclusion criteria

- (1) Extrapulmonary causes of acute respiratory failure
 - (a) Stroke.
 - (b) Neuromuscular disorders.
 - (c) Drug induced.
- (2) Nonmedical causes of acute respiratory failure, for example trauma.
- (3) Patients older than 70 years or younger than 18 years of age.
- (4) Postcardiac arrest.
- (5) Advanced malignancy with or without metastasis.

For a more detailed analysis, patients' respiratory illnesses were categorized into obstructive, restrictive, and combined breathing disorders according to their medical history, and clinical and radiological assessment.

Methods

- (1) All selected patients were intubated and connected to the ventilator using an Inspiration Events ventilator. Settings were tailored according to the clinical condition indicating mechanical ventilation and monitoring of clinical, laboratory, and lung mechanics data during the course of ventilation. The medical therapy and nursing care were individualized according to the original problem indicating mechanical ventilation. Analgo/sedation was achieved with Midazolam (bolus and/or infusion) and/or fentanyl (bolus and/or infusion) with dose adjustment according to the clinical indication and response considering morning sedation vacation for reassessment.
- (2) The following was performed for every patient:
 - (a) Clinical evaluation including assessment of history and examination.
 - (b) Admission and follow-up chest radiograph.
 - (c) Laboratory data on admission and during ICU stay including complete blood picture, electrolytes, arterial blood gases, and complete metabolic profile. The thyroid profile was added if indicated.

- (d) Admission severity scoring through the APACHE II score. Patients were subdivided according to severity into two groups: group I included patients with APACHE II score of at least 32.5 and group II included patients with APACHE II score of less than 32.5 (statistically selected).
- (e) Patient-machine synchronization was assessed twice daily using the Riker Sedation/Agitation Scale [19]. For statistical analysis, patients were categorized into comfortable (scale number 4), which was considered an indirect indicator of good synchronization, and noncomfortable (scale 5, 6, 7, 1, 2, 3), which was considered an indirect indicator of suboptimal synchronization.
- (f) Recording duration under sedation, total duration of ventilation, weaning duration, and total ICU stay.
- (g) Recording complications (including reventilation within 24 h after extubation) and mortality.
- (h) Monitoring of patients according to ICU guidelines.
- (i) Mechanical ventilation for both pressure and flow groups was started by using the pressure-control or volume-control conventional mode or the pressure regulating volume control dual mode or alternating between them, that is combined mode. When the patients were placed on the spontaneous-breath mode, the pressure trigger was set at -2 cmH₂O and the flow trigger was set at 2 l/min. Nursing care and pharmacological management were tailored dynamically according to every patient scenario.
- (j) Weaning of patients was achieved using either pressure support and or T piece trials after completing a daily weaning checklist according to Corrado *et al.* [20].

Statistical methods

The data were recorded on a report form, tabulated, and analyzed using the computer program statistical package for social science, version 16.

Descriptive data

Descriptive statistics were calculated for the data in the form of:

- (1) Mean and SD for quantitative data.
- (2) Frequency and distribution for qualitative data.

Analytical statistics

In the statistical comparison between the different groups, the significance of difference was tested using one of the following tests:

- (1) Student's *t*-test and Mann-Whitney test (*Z*): used to compare the mean of two groups of quantitative parametric and nonparametric data, respectively.
- (2) Intergroup comparison of categorical data was performed using the χ^2 -test (χ^2 -value) and the Fisher exact test.

A *P* value of 0.05 or less was considered statistically significant (S), a *P* value of more than 0.05 was considered statistically insignificant, and a *P* value of less than 0.01 was considered highly significant (HS) in all analyses.

Results

The FT group had more severe illness compared with the PT group, with APACHE11 scores of 42.70 and 38.00, respectively, and with a statistically significant difference (*P* = 0.04) (Tables 1–4).

There was no significant difference between both PT and FT groups in weaning duration (2.78 vs. 2.64 days with *P* = 0.867), duration of ventilation (4.67 and

Table 1 Demographic data, APACHE II score, and functional diagnosis of pressure-triggering versus flow-triggering groups

Variables on admission	Pressure (<i>n</i> = 50)	Flow (<i>n</i> = 50)	Test	<i>P</i>
Age (mean ± SD)	55.30 ± 14.89	53.78 ± 15.76	<i>t</i> = 0.496	0.621
Sex [<i>n</i> (%)]				
Male	23 (46.0)	27 (54.0)	χ^2 = 0.640	0.424
Female	27 (54.0)	23 (46.0)		
Smoking [<i>n</i> (%)]				
Nonsmoker	27 (54.0)	27 (54.0)	FET = 8.256	0.016
Smoker	16 (32.0)	23 (46.0)		
Exsmoker	7 (14.0)	0		
APACHE II (mean ± SD)	38.00 ± 10.74	42.70 ± 11.79	<i>t</i> = 2.084	0.040
Functional diagnosis [<i>n</i> (%)]				
Obstructive [23 (23%)]	9 (18)	14 (28)	χ^2 = 1.78	0.411
Restrictive [56 (56%)]	31 (62)	25 (50)		
Combined [21 (21%)]	10 (20)	11 (22)		

APACHE II, Acute Physiology and Chronic Health Evaluation II; FET, Fisher exact test; *t*, Student's *t*-test; Statistically significant at *P* ≤ 0.05.

Table 2 Mechanical ventilator data in pressure versus flow triggering groups

	Pressure (n = 50)	Flow (n = 50)	Test	P
History of MV [n (%)]	9 (18.0)	8 (16.0)	$\chi^2 = 0.071$	0.790
Mode [n (%)]				
Conventional	11 (22.0)	8 (16.0)	$t = 0.597$	0.742
Dual	35 (70.0)	38 (76.0)		
Both	4 (8.0)	4 (8.0)		
Weaning duration (mean \pm SD) (days)	5.48 \pm 3.35	2.76 \pm 1.44	$t = 5.274$	<0.001
Duration of ventilation (mean \pm SD) (days)	8.18 \pm 5.69	4.72 \pm 2.49	$t = 3.938$	<0.001
Reventilation [n (%)]	9 (18)	11 (22)	$t = 0.25$	0.62
Pre-extubation PaO ₂ /FIO ₂ (mean \pm SD)	196.10 \pm 60.61	266.72 \pm 93.58	$t = 4.479$	<0.001
Pre-extubation PaCO ₂ (mean \pm SD)	48.17 \pm 15.05	36.33 \pm 15.88	$t = 1.51$	0.149
Self extubation [n (%)]	10 (20)	7 (14)	$t = 0.638$	0.425

FiO₂, fraction of inspired oxygen; MV, minute ventilation; PaCO₂, arterial carbon dioxide tension; PaO₂, arterial oxygen tension; t, Student's t-test; Statistically significant at $P \leq 0.05$.

Table 3 Pressure versus flow triggering in terms of impact on outcome (total duration of ICU stay, complications, and mortality)

	Pressure (n = 50)	Flow (n = 50)	Test	P
Total duration of ICU stay (mean \pm SD) (days)	9.86 \pm 5.56	5.80 \pm 2.91	$t = 4.577$	<0.001
Complications [n (%)]	19 (38.0)	17 (34.0)	$\chi^2 = 0.174$	0.677
Mortality [n (%)]				
Death	22 (44.0)	18 (36.0)	$\chi^2 = 0.667$	0.414
Survival	28 (56.0)	32 (64.0)		

t, Student's t-test; Statistically significant at $P \leq 0.05$.

4.07 days, $P = 0.547$), and total duration of ICU stay (6.56 vs. 4.93 days, $P = 0.181$) (Table 5).

Weaning duration, duration of ventilation, total duration of ICU stay, and duration of use of sedation were significantly shorter in the FT group than in the PT group (2.52 vs. 6.5, 4.6 vs. 9.7, 5.68 vs. 11.4, and 2.24 vs. 6.52 days, respectively, with $P < 0.001$ for all) (Table 6).

Weaning duration, duration of ventilation, total duration in ICU stay, and duration of using sedation were insignificantly shorter in the FT group than in the PT group (3.45 vs. 4.60 days, $P = 0.197$; 5.73 vs. 6.40 days, $P = 0.649$; 7.18 vs. 8.00 days, $P = 0.626$; 2.82 vs. 4.50 days, respectively, $P = 0.12$) (Table 7).

Weaning duration, duration of ventilation, total duration of ICU stay, and duration of using sedation were statistically shorter in the FT group than in the PT group (2.64 vs. 5.60, 4.64 vs. 7.94, 5.69 vs. 9.49, 2.33 vs. 5.26 days, respectively, with $P < 0.001$ for all).

The pre-extubation oxygenation index was significantly higher in the FT group than in the PT group (275.95 vs. 189.06, with $P < 0.001$) (Table 8).

Weaning duration, duration of ventilation, total duration of ICU stay, and duration of use of sedation were nonsignificantly shorter in the FT group compared with the PT group (3.18 vs. 5.20 days, $P = 0.148$; 5.00 vs. 8.73 days, $P = 0.222$; 6.18 vs. 10.73 days, $P = 0.129$; 2.64 vs. 5.40 days, respectively, $P = 0.098$) (Figs. 1–13).

Discussion

The PT group included 50 patients; 46% were men, mean age 55.30 years, and the FT group included 50 patients; 54% were men, mean age 53.78 years, and there was no statistical difference in age and sex.

There were significantly higher numbers of smokers were in the FT group (46.0%) than in the PT group (32.0%) ($P = 0.016$).

Patients were classified into three categories according to the main initial problem: obstructive pulmonary disorder group (23%) (which included patients with COPD, asthma, bronchiectasis, overlap syndrome).

Restrictive pulmonary disorder group (56%) (which included patients with pneumonia, ARDS, pulmonary fibrosis, obesity, hypoventilation syndrome) and both combined obstructive and restrictive group (21%).

Pneumonia was the most common cause of ICU admission and mechanical ventilation in both groups.

Goulet *et al.* reported that no study of triggering has assessed the outcome. Most studies, similar to theirs, have been short-term evaluations of physiologic response to various forms of triggering. It is unknown whether one approach to triggering is superior to others with respect to the duration of mechanical ventilation or other indices of morbidity. Because FT increases the cost and complexity of triggering, it would be of

interest to know whether the type of triggering affects outcome.

Therefore, we focused on the evaluation of the two triggerings in terms of the following outcome parameters: weaning duration, total ventilation days, total duration of ICU stay, and duration of using sedations.

There was a statistically significantly shorter duration of weaning in the FT group (2.76 days)

than in the PT group (5.48 days) (with $P < 0.001$). The total duration of ventilation was also shorter in the FT group (4.72 days) compared with (8.18 days) the PT group, which was statistically significant ($P < 0.001$).

The oxygenation index was better in the FT group than in the PT group (266.72 vs. 196.10, respectively), which was a statistically significant difference ($P < 0.001$).

Table 4 Pressure versus flow triggering outcome in the obstructive breathing disorders group

	Pressure ($n = 9$)	Flow ($n = 14$)	Test	P
Weaning duration (mean \pm SD) (days)	2.78 \pm 1.92	2.64 \pm 1.82	$t = 0.170$	0.867
Duration of ventilation (mean \pm SD) (days)	4.67 \pm 2.24	4.07 \pm 2.30	$t = 0.612$	0.547
Need for sedation (mean \pm SD) (days)	1.78 \pm .67	2.36 \pm 1.65	$t = 0.998$	0.330
Duration of ICU stay (mean \pm SD) (days)	6.56 \pm 2.79	4.93 \pm 2.73	$t = 1.383$	0.181
Pre-extubation PaCO ₂ (mean \pm SD) (mmHg)	48.0 \pm 0.0	36.33 \pm 15.88	$t = 1.51$	0.149
Pre-extubation PaO ₂ /FIO ₂ (mean \pm SD)	227.44 \pm 31.02	216.00 \pm 84.82	$t = 0.459$	0.652
Impact on patient comfort [n (%)]				
Not comfortable	1 (11.1)	2 (14.3)	FET = 0.049	1.0
Comfortable	8 (88.9)	12 (85.7)		
Self extubation [n (%)]	2 (22.2)	2 (14.3)	FET = 0.24	1.0
Complications [n (%)]	1 (11.1)	1 (7.1)	FET = 0.109	1.0
Reventilation [n (%)]	3 (33.3)	2 (14.3)	FET = 1.48	0.343

t , Student's t -test; Statistically significant at $P \leq 0.05$.

Table 5 Pressure versus flow triggering outcome in the restrictive breathing disorders group

	Pressure ($n = 31$)	Flow ($n = 25$)	Test	P
Weaning duration (mean \pm SD) (days)	6.55 \pm 3.48	2.52 \pm 1.05	$t = 6.109$	<0.001
Duration of ventilation (mean \pm SD) (days)	9.77 \pm 6.48	4.64 \pm 1.73	$t = 3.844$	<0.001
Pre-extubation PaCO ₂ (mean \pm SD)	42.25 \pm 11.9	34.2 \pm 16.67	$t = 0.871$	0.401
Pre-extubation PaO ₂ /FIO ₂ (mean \pm SD)	181.35 \pm 55.32	307.64 \pm 87.33	$t = 6.585$	<0.001
Impact on patient comfort [n (%)]				
Not comfortable	12 (38.7)	9 (36.0)	$\chi^2 = 0.043$	0.835
Comfortable	19 (61.3)	16 (64.0)		
Need for sedation (mean \pm SD) (days)	6.58 \pm 3.36	2.24 \pm 1.05	$t = 6.784$	<0.001
Self-extubation [n (%)]	6 (19.4)	3 (12.0)	FET = 699	0.716
Duration of ICU stay (mean \pm SD) (days)	11.42 \pm 6.21	5.68 \pm 2.04	$t = 4.425$	<0.001
Complications [n (%)]	12 (38.7)	10 (40.0)	$\chi^2 = 0.01$	0.922
Reventilation [n (%)]	5 (16.1)	5 (20.0)	$\chi^2 = 0.141$	0.707

FET, Fisher exact test; t , Student's t -test; Statistically significant at $P \leq 0.05$.

Table 6 Pressure versus flow triggering outcome in the combined breathing disorders group

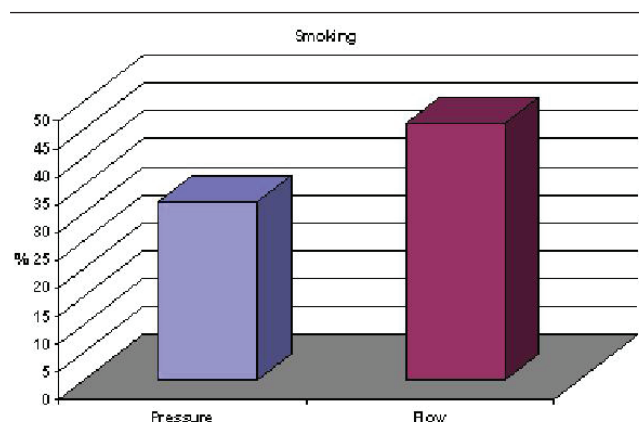
	Pressure ($n = 10$)	Flow ($n = 11$)	Test	P
Weaning duration (mean \pm SD) (days)	4.60 \pm 2.32	3.45 \pm 1.57	$t = 1.336$	0.197
Duration of ventilation (mean \pm SD) (days)	6.40 \pm 2.67	5.73 \pm 3.82	$t = 0.462$	0.649
Pre-extubation PaCO ₂ (mean \pm SD)	72.0 \pm 0.0	47.0 \pm 0.0	—	—
Pre-extubation PaO ₂ /FIO ₂ (mean \pm SD)	213.60 \pm 82.91	238.27 \pm 81.10	$t = 0.689$	0.499
Impact on patient comfort [n (%)]				
Not comfortable	2 (20.0)	5 (45.5)	FET = 2.12	0.361
Comfortable	8 (80.0)	6 (54.5)		
Need for sedation (mean \pm SD) (days)	4.50 \pm 2.68	2.82 \pm 2.04	$t = 1.629$	0.120
Self extubation [n (%)]	2 (20.0)	2 (18.2)	FET = 0.011	1.0
Duration of ICU stay (mean \pm SD) (days)	8.00 \pm 3.09	7.18 \pm 4.31	$t = 0.495$	0.626
Complications [n (%)]	2 (20.0)	3 (27.3)	FET = 0.153	1.0
Reventilation [n (%)]	1 (10.0)	4 (36.3)	FET = 2.818	0.311

t , Student's t -test; Statistically significant at $P \leq 0.05$.

Ventilation was also better in the FT group compared with the PT group (pre-extubation PaCO₂ was 36.33 and 48.14 mmHg, respectively). However, this was a statistically insignificant difference ($P = 0.149$).

Most of self-extubation occurred in the PT group (20%) in compare to only (14%) of the FT group, without significant difference ($P = 0.425$).

Fig. 1

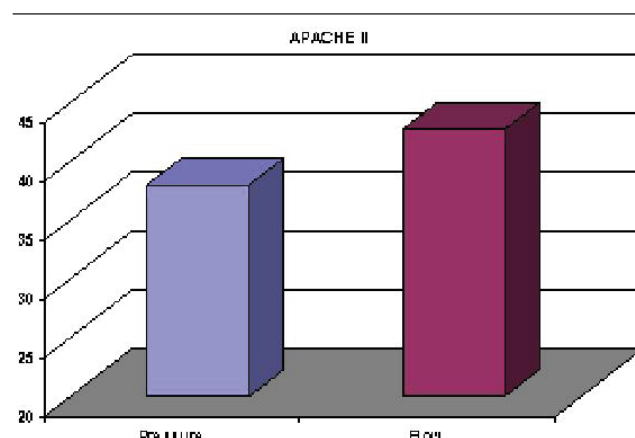


Incidence of smoking.

The total duration of ICU stay was significantly shorter in the FT group than the PT group (5.80 vs. 9.86 days, respectively, with $P < 0.001$).

Although there were greater complications in the PT group (38%) versus (34%) in the FT group, there were no significant differences ($P = 0.677$),

Fig. 2



APACHE II score in pressure versus flow triggering groups.

Table 7 Pressure versus flow triggering outcome in patients with APACHE II score more than 32.5

	Pressure (n = 35)	Flow (n = 39)	Test	P
Weaning duration (mean ± SD) (days)	5.60 ± 2.95	2.64 ± 1.39	t = 5.418	<0.001
Duration of ventilation (mean ± SD) (days)	7.94 ± 2.85	4.64 ± 2.61	t = 5.203	<0.001
Pre-extubation PaCO ₂ (mean ± SD) (mmHg)	48.67 ± 11.02	35.67 ± 21.94	t = 0.917	0.411
Pre-extubation PaO ₂ /FIO ₂ (mean ± SD)	189.06 ± 51.24	275.95 ± 96.28	t = 4.914	<0.001
Impact on patient comfort [n (%)]				
Not comfortable	6 (27.3)	9 (30.0)	χ ² = 0.046	0.83
Comfortable	16 (72.7)	21 (70.0)		
Need for sedation (mean ± SD) (days)	5.26 ± 2.55	2.33 ± 1.34	t = 6.264	<0.001
Self extubation [n (%)]	3 (13.6)	5 (16.7)	FET = 0.09	1.0
Duration of ICU stay (mean ± SD) (days)	9.49 ± 2.92	5.69 ± 2.99	t = 5.503	<0.001
Complications [n (%)]	5 (22.7)	4 (13.3)	FET = 1.047	0.468
Reventilation [n (%)]	3 (13.6)	7 (23.3)	FET = 1.039	0.488

FET, Fisher exact test; t, Student's t-test; Statistically significant at $P \leq 0.05$.

Table 8 Pressure versus flow triggering outcome in patients with APACHE II score less than 32.5

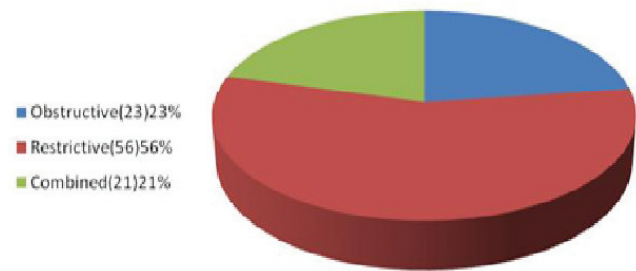
	Pressure (n = 15)	Flow (n = 11)	Test	P
Weaning duration (mean ± SD) (days)	5.20 ± 4.25	3.18 ± 1.60	t = 1.494	0.148
Duration of ventilation (mean ± SD) (days)	8.73 ± 9.65	5.00 ± 2.10	t = 1.254	0.222
Pre-extubation PaCO ₂ (mean ± SD) (mmHg)	47.67 ± 21.08	36.56 ± 15.04	t = 1.02	0.334
Pre-extubation PAO ₂ /FIO ₂ (mean ± SD)	212.53 ± 77.90	234.00 ± 78.60	t = 0.692	0.496
Impact on patient comfort [n (%)]				
Not comfortable	9 (32.1)	7 (35.0)	χ ² = 0.043	0.836
Comfortable	19 (67.9)	13 (65.0)		
Need to sedation (mean ± SD) (days)	5.40 ± 5.04	2.64 ± 1.91	1.722	0.098
Self extubation [n (%)]	7 (25.0)	2 (10.0)	FET = 2.6	0.271
Total duration of ICU stay (mean ± SD) (days)	10.73 ± 9.28	6.18 ± 2.68	t = 1.571	0.129
Complications [n (%)]	10 (35.7)	10 (50.0)	χ ² = 0.98	0.322
Reventilation [n (%)]	6 (21.4)	4 (20.0)	FET = 0.014	1.0

FET, Fisher exact test; t, Student's t-test; Statistically significant at $P \leq 0.05$.

but it is worth mentioning that pneumothorax was more common in the FT group as it occurred in eight patients either alone or in combination with other complications whereas it occurred in only two patients in the PT group, and this represents an advantage of PT.

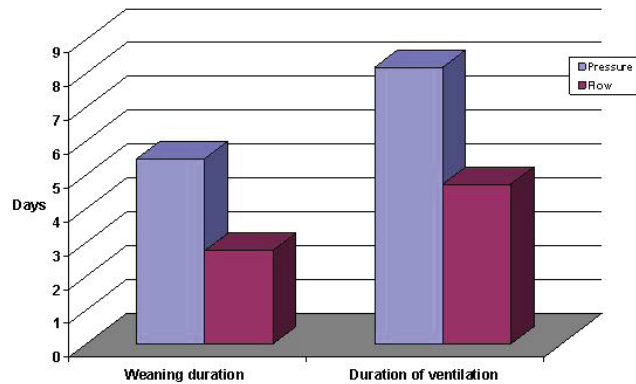
Mortality was also higher in the PT group (44.0%) compared with the FT group (36.0%), but with no significant difference ($P = 0.414$).

Fig. 3



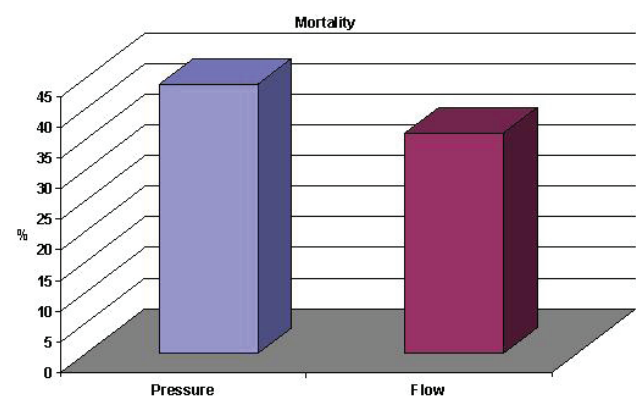
Functional diagnosis of the cases studied.

Fig. 5



Weaning duration and duration of ventilation in pressure versus flow triggering.

Fig. 7

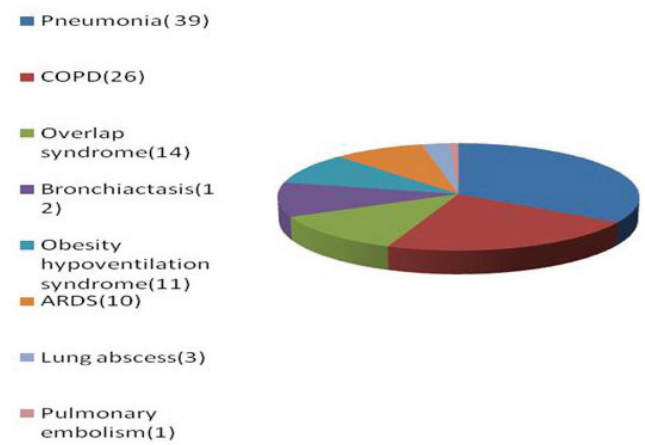


Incidence of mortality in the pressure versus flow triggering groups.

Reventilation was performed more in the FT group (22%) compared with the PT group (18%), but no significant difference was detected ($P = 0.62$).

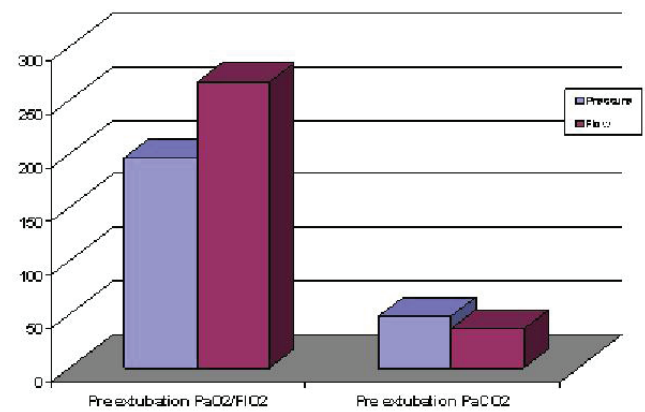
The patients in the FT group had more severe illness compared with those in the PT group, with APACHE11 scores of 42.70 and 38.00, respectively ($P = 0.04$).

Fig. 4



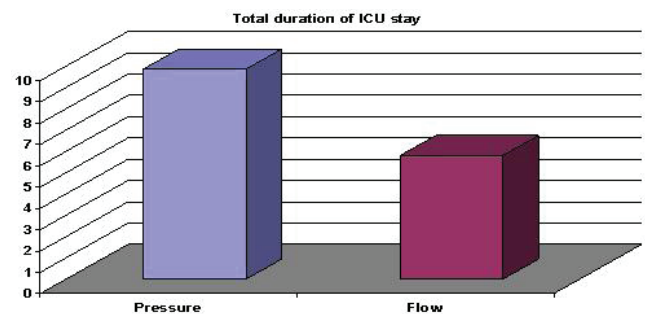
Descriptive data of patients' primary diagnosis.

Fig. 6



Pre-extubation PaO₂/FIO₂ and PaCO₂ in the pressure versus flow triggering group.

Fig. 8



Total duration of ICU stay in pressure versus flow triggering.

Overall, in this study, FT was superior to PT with respect to the duration of mechanical ventilation, duration of weaning, ICU length of stay, and oxygenation index before extubation. There was also a trend toward better ventilation as determined by the level of PaCO₂ before extubation and lower mortality in the FT group. Taking into consideration the finding that patients in the FT group had more severe illness compared with the patients in the PT group augments the satisfaction with the conclusion of FT superiority in the above outcomes.

Although the duration of weaning and the total duration of ventilation were shorter in the FT group, reventilation was performed more in the FT group. This may be related to the severity of illness, which was higher in the FT group than the PT group (APACHE II in the FT group was 42.70 and that in the PT group was 38).

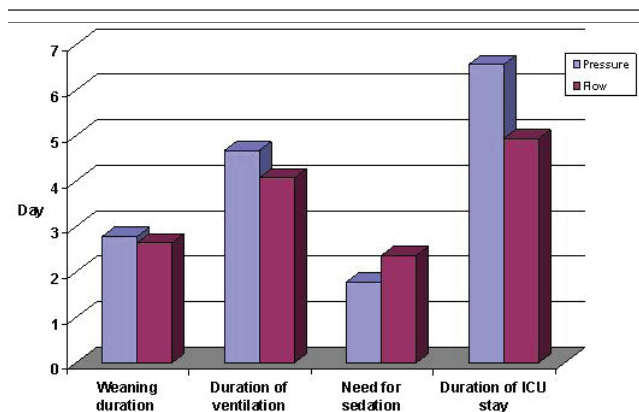
This is with agreement with Sassoon *et al.* [22] and Giuliani *et al.* [23], who reported that FT is usually

associated with a reduction in breathing effort compared with PT, although a significant benefit was not found consistently in all studies.

However, Correa *et al.* [24] concluded that during the pressure trigger ventilation, the minute ventilation was greater than that in the FT ventilation without affecting the other ventilatory parameters when they evaluated 20 mechanically ventilated adult ICU patients recovering from acute respiratory failure who were ventilated with a pressure support of 15 cmH₂O, PEEP of 5 cmH₂O, and FIO₂ of 40%. The patients were ventilated by two different trigger systems during pressure support ventilation (PSV): a flow trigger of 2 l/min or a pressure trigger (-2 cmH₂O) during PSV. They measured the respiratory rate, expiratory tidal volume, minute ventilation, VCO₂, VTCO₂, ETCO₂, SpO₂, mean arterial pressure, and heart rate after 15 min in each study situation.

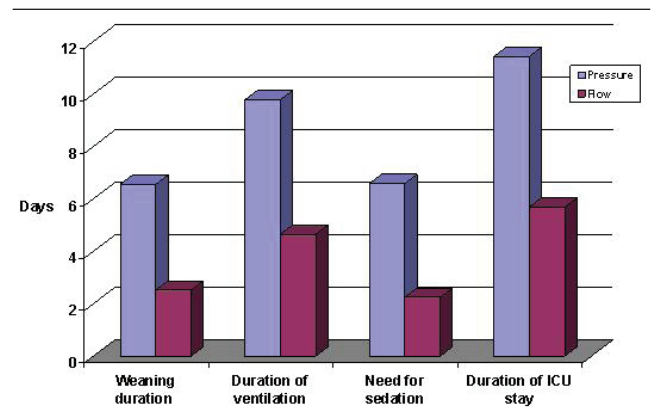
In another study, Goulet *et al.* [21] compared pressure versus FT during PSV in adult mechanically

Fig. 9



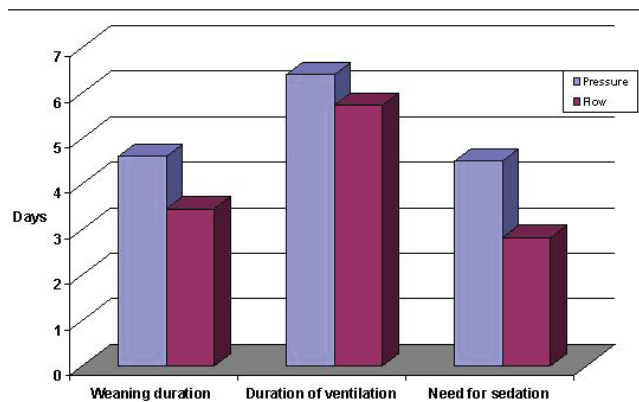
Weaning duration, duration of ventilation, need for sedation, and total duration of ICU stay in pressure versus flow triggering among obstructive pulmonary disorder patients.

Fig. 10



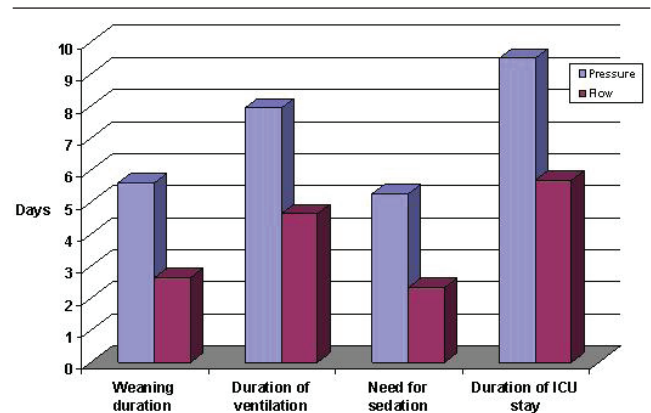
Weaning duration, duration of ventilation, need for sedation, and total duration of ICU stay in pressure versus flow triggering among restrictive pulmonary disorder patients.

Fig. 11



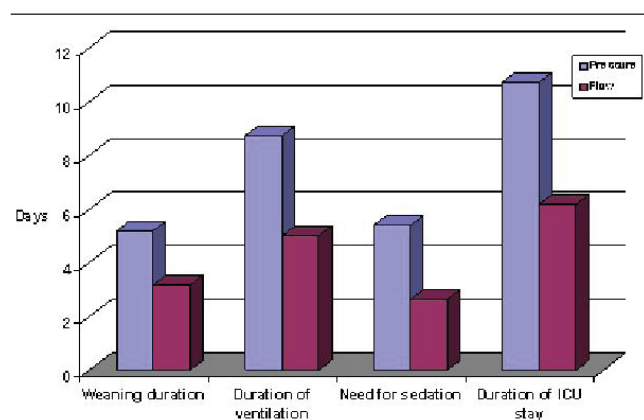
Weaning duration, duration of ventilation, and need for sedation in pressure versus flow triggering among patients with combined pulmonary disorders.

Fig. 12



Weaning duration, duration of ventilation, need for sedation, and total duration of ICU stay in pressure versus flow triggering among patients with APACHE II score more than 32.5.

Fig. 13



Weaning duration, duration of ventilation, need for sedation, and total duration of ICU stay in pressure versus flow triggering among patients with APACHE II score less than 32.5.

ventilated patients. Their study included 10 patients recovering from acute respiratory failure: median PSV 10 cmH₂O, median PEEP 5 cmH₂O; all were in a hemodynamically stable condition and four trigger sittings were randomly applied: pressure -0.5 cmH₂O, pressure -10 cmH₂O, and base flow 5 l/min with a flow sensitivity of 2 l/min and base flow 10 l/min with a flow sensitivity of 3 l/min. They found that a pressure trigger of -0.5 cmH₂O was consistently more sensitive than the other three triggering methods, but we cannot rely totally on these results because of the small population of this study. Also, they evaluated four triggering settings that they used in their clinical practice and the superiority was only evident with -0.5 cmH₂O compared with -2 cmH₂O in this current study. In addition, this study was carried out on stable weanable patients recovering from acute respiratory failure whereas the current study was carried out on patients with acute respiratory failure throughout the period of mechanical ventilation once they had resumed spontaneous breathing.

In another point of view, Tantucci *et al.* [25] concluded that the application of either a pressure-triggered or a flow-triggered system during pressure-support ventilation did not significantly affect short-term changes in gas exchange, respiratory mechanics, and inspiratory workload in 16 orotracheally intubated adult patients recovering from acute respiratory failure of various etiologies, without chronic obstructive pulmonary disease. Again, this study was carried out on stable patients recovering from acute respiratory failure whereas the current study was carried out on severely ill patients throughout the period of mechanical ventilation once they had resumed spontaneous breathing.

The investigators consider work of breathing (WOB) an important issue that should have been

studied and compared between the FT and PT groups. WOB assessment usually entails evaluation of trans-diaphragmatic pressures, which could not been evaluated in the current study for technical reasons and this is one of the limitations of this study. Nevertheless, WOB was substituted in this study with other parameters that indirectly reflect patient-ventilator synchrony, namely, patient sense of comfort on the ventilator as assessed by the Riker Sedation-Agitation Score and the need for sedation. Both parameters reflected better synchrony with FT. The finding of less breath effort with FT compared with PT was reported several years ago by Sassoon *et al.* [22], and confirmed by Giuliani *et al.* [23], who reported that inspiratory muscle effort (as reflected by the pressure-time product) was less with flow-triggered than with pressure-triggered SIMV during both mandatory and spontaneous breaths, with a better patient-ventilator interaction.

In addition, Branson *et al.* [26], concluded that FT reduces the WOB compared with PT, irrespective of the ventilator used. The reduction in WOB during FT is related to improved responsiveness and changes in the post-trigger phase, suggesting that FT is a superior technique.

When the patients were divided into subgroups, comparison between the two triggering methods in the obstructive pulmonary disorders group showed no significant difference between both PT and FT groups in weaning duration (2.78 vs. 2.64 days with $P = 0.867$), duration of ventilation (4.67 and 4.07 days, $P = 0.547$), and total duration of ICU stay (6.56 vs. 4.93 days, $P = 0.181$).

Although ventilation (pre-extubation PaCO₂) was better in the FT group (36.33 mmHg) compared with (48.0 mmHg) the PT group, there was no significant difference ($P = 0.149$). However, oxygenation (pre-extubation PaO₂/FIO₂) was better in the PT group (227.44 mmHg) than in the FT group (216.00 mmHg), again with no significant differences ($P = 0.652$).

Duration of need for sedation was prolonged in the FT group than in the PT group (2.36 vs. 1.78 days, respectively), with no statistically significant differences ($P = 0.330$).

Patients were more comfortable (Riker Sedation-Agitation Scale) in the PT group (88.9%) than in the FT group (85.7%), with no significant difference ($P = 1.0$).

Self-extubation was performed more in the PT group (22.2%) than in the FT group (14.3%), with no significant differences ($P = 1.0$).

Reventilation was performed more in the PT group (33.3%) compared with (14.3%) the FT group, with no significant difference ($P = 0.343$).

In terms of complications, 93% of patients in the FT group were free from complications compared with 89% of patients in the PT group, with no significant difference ($P = 1.0$).

In a study carried out by Ranieri *et al.* [27], it was concluded that application of FT requires less effort to initiate inspiration and provides a positive end-expiratory pressure level that can unload the respiratory muscles by reducing the effect of PEEP_i. This study was carried on six COPD patients with acute respiratory failure ready to be weaned; esophageal and gastric pressures were measured by intraesophageal and intragastric balloon pressure sensors, minute ventilation, and breathing patterns, and pressure–time product of the respiratory muscles and diaphragm was obtained during spontaneous ventilation through a mechanical ventilator (Puritan-Bennett 7200ae). They found that the inspiratory muscles' effort necessary to overcome the triggering system overestimated PEEP_{i,dyn} measurement by an amount equal to 49 ± 2 and $58 \pm 3\%$ during pressure and FT, respectively. FT increased tidal volume and minute ventilation and decreased pressure–time product of the respiratory muscles and diaphragm. This benefit in COPD patients was not investigated thoroughly in the current study, but FT showed a superior trend compared with PT in ventilation, self-extubation, reventilation, and occurrence of complications, and PT showed a superior trend in oxygenation, duration of sedation, comfortability, and synchronization, but with no statistical significance in either case.

Also, Nava *et al.* [28] concluded that in patients with COPD recovering from an acute exacerbation, FT reduces the inspiratory effort during both PSV and assisted controlled mode (A/C) compared with PT. They attributed the findings to a reduction in PEEP_{i,dyn} and the time of valve opening with a flow trigger. The study compared the effect of FT (1 and 5 l/min) and PT ($-1 \text{ cmH}_2\text{O}$) on inspiratory effort during PSV and A/C delivered noninvasively using a full face mask.

Among patients with restrictive pulmonary disorders, weaning duration, duration of ventilation, total duration of ICU stay, and duration of need to sedation were significantly shorter in the FT group than in the PT group (2.52 vs. 6.5, 4.6 vs. 9.7, 5.68

vs. 11.4, and 2.24 vs. 6.52 days, respectively, with $P < 0.001$ for all).

Oxygenation (pre-extubation $\text{PaO}_2/\text{FIO}_2$) was significantly higher in the FT group than in the PT group (307.64 vs. 181.35, $P < 0.001$), but there was no significant difference between the two groups in ventilation [pre-extubation PaCO_2 : 34.2 mmHg in the FT group and 42.2 mmHg in the PT group ($P = 0.41$)].

Patients were more comfortable in the FT group than in the PT group (64.0 vs. 61.3%), with insignificant differences.

No significant differences were detected in self-extubation, although it was increased in the PT group (19.4%) than in the flow-triggering FT group (12.0%). Reventilation was performed more in the FT group (20.0%) compared with the PT group (16.1%), with no significant differences ($P = 0.707$). There was no significant difference between the two groups in complications; 60.0% of the patients in the FT group were free from complications compared with 61.3% of patients in the PT group ($P = 0.922$).

From the above results, we can conclude that FT is superior to PT in restrictive breathing disorders in the following: weaning duration, duration of ventilation, total duration of ICU stay, duration of need to sedation, and ventilation. In the FT group, there was better synchrony between the patients and the ventilator and the patients also felt more comfortable. However, the reventilation rate was lower in the PT group.

Therefore, in this study, the superiority of FT was most evident in patients with restrictive compared with obstructive pulmonary disorders. This may be related to the nature and pathology of illness.

A combined pulmonary disorder study showed that weaning duration, duration of ventilation, total duration in ICU stay, and duration of using sedation were insignificantly shorter in the FT group than in the PT group (3.45 vs. 4.60 days, $P = 0.197$; 5.73 vs. 6.40 days, $P = 0.649$; 7.18 vs. 8.00 days, $P = 0.626$; 2.82 vs. 4.50 days, $P = 0.120$, respectively).

There was also improvement in ventilation (pre-extubation PaCO_2) in the FT group (47.0 mmHg) than in the PT group (72.0 mmHg), and in oxygenation (pre-extubation $\text{PaO}_2/\text{FIO}_2$) in the FT group than in the PT group (238.27 vs. 213.60), but this was statistically insignificant.

The level of comfort was better in the PT group than the FT group (80.0 vs. 54.5%), but the differences were statistically insignificant.

Self-extubation was performed more in the PT group (20.0%) compared with the FT group (18.2%), with no significant difference. However, reventilation was performed more in the FT group (36.3%) compared with (10.0%) the PT group, but this was not significant ($P = 0.311$).

In the PT group, 80.0% patients were free from complications compared with 72.7% patients in the FT group, but this was insignificant ($P = 1.0$).

In terms of APACHE II scoring, Forte *et al.* [29] reported that this score accurately reflects the degree of physiological derangement and correlates with subsequent clinical course and length of ICU stay. The APACHE II scoring system is used widely in general ICU for comparative audit, evaluative research, and clinical management of individual patients. The number of acute organ failures has been shown to be an important determinant of prognosis in critically ill patients admitted to an ICU.

In this study, APACHE II scoring was applied and the patients were subdivided into those with the most severe illness (using APACHE II score >32.5 as a cut-off value), 74 cases, and less severe illness (APACHE II score <32.5), 26 cases.

The patients in the FT group had more severe illness than those in the PT group, with APACHE II scores of 42.70 and 38.00, respectively, and P equal to 0.04, which was considered statistically significant.

It was obvious in patients with the most severe illness that FT was superior to PT in weaning duration, duration of ventilation, total duration of ICU stay, and duration of need for sedation. All these durations were significantly shorter in the FT group than in the PT group (2.64 vs. 5.60, 4.64 vs. 7.94, 5.69 vs. 9.49, and 2.33 vs. 5.26 days, respectively, with $P < 0.001$ for all). Also, the FT patients showed better oxygenation as indicated by $\text{PaO}_2/\text{FIO}_2$ (275.95 vs. 189.06 in PT). Although better ventilation was also evident (PaCO_2 level 35.67 vs. 48.67 in PT), it was statistically insignificant. In the less severe cases, there were no statistically significant differences between FT patients and PT in all parameters. However, FT patients showed a trend toward better oxygenation and ventilation and shorter durations of weaning, ventilation, total duration of ICU stay, and duration of need or sedation. These findings suggest that the efficiency and superiority of FT become obvious in challenging situations when patients have more critical illness and need the most optimized interventions. In patients with good recovery, the difference between the two triggering systems is too small to manifest.

In the current study, all patients were investigated using a single ventilator brand: Inspiration Events. Although the use of other brands may influence the results, other studies using other brands have shown similar results. Sassoon *et al.* [30], reported a reduction in WOB during FT with the Puritan Bennett 7200ae. The type of pulmonary illness, its severity, and the level of triggering (compared with other studies) were the most influencing factors in the current study.

From the above results, we can conclude that FT may be considered better than PT in ventilating acute respiratory failure patients with a restrictive pattern and those with a higher severity scoring. However, in obstructive and mixed ventilatory impairment, use of either of them does not make a difference.

Conclusion

FT may be considered to be better than PT in ventilating acute respiratory failure patients with a restrictive pattern and those with a higher severity scoring. In obstructive and mixed ventilatory impairment, use of either of them does not make a difference.

Recommendations

- (1) FT should be considered in patients with acute respiratory failure because of restrictive ventilatory impairment and those with more severe illness.
- (2) Further studies are recommended for more justification of this conclusion.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References

- 1 Grippi MA. Respiratory failure: an overview. In: Fishman JA, Grippi MA, Kaiser LR, Senior RM, (editors) *Fishman's pulmonary diseases and disorders*. 3rd ed. The McGraw-Hill Companies Inc.; 1998. 165:2525–2535.
- 2 Kim HJ, Ingbar DH. Acute respiratory failure. In: Parsons PE, Hefner JE(editors) *Pulmonary/respiratory therapy secrets*. 3rd ed. Elsevier Inc.; 2006. 62:459–468.
- 3 Hudson LD. Acute respiratory failure overview (Ch. 140). In: Fishman AP, (editor) *Pulmonary disease and disorders*. 2nd ed. Mc Graw-Hill Book Company; 1988:2189–2198.
- 4 Mador MJ, Tobin MJ. Acute respiratory failure (Ch. 19). In: Carverly, PMA, Pride NB, (editors) *Chronic obstructive pulmonary disease*. 1st ed. Chapman & Hall; 1995:461–494.
- 5 Sherman C, Hudson LD. Complications of acute respiratory failure. In: Bone RC, George RB, Hudson LD, editors *Acute respiratory failure*. New York: Churchill Livingstone; 1987. 317–334.
- 6 Bonten MJ, Kollef MH, Hall JB. Risk factors for ventilator-associated pneumonia: from epidemiology to patient management. *Clin Infect Dis* 2004; **38**:1141–1149.
- 7 Auriant I, Jallot A, Hervé P, Cerrina J, Le Roy Ladurie F, Fournier JL, *et al.* Noninvasive ventilation reduces mortality in acute respiratory failure following lung resection. *Am J Respir Crit Care Med* 2001; **164**:1231–1235.
- 8 Mehta S, Hill NS. Noninvasive ventilation. *Am J Respir Crit Care Med* 2001; **163**:540–577.

- 9 Tobin MJ. Mechanical ventilation. *N Engl J Med* 1994; **330**:1056–1061.
- 10 Moxam J. Treatment by physical means: ventilation, physiotherapy and rehabilitation. In: Brewis RAL, Corrin B, Geddes DM, Gibson GJ, (editors) *Respiratory medicine*. 2nd ed. *W B Saunders Company* 1995; **13**:447–467.
- 11 Tobin MJ. Respiratory monitoring. *JAMA* 1991; **1**:34.
- 12 Marini JJ, Smith TC, Lamb VJ. External work output and force generation during synchronized intermittent mechanical ventilation. Effect of machine assistance on breathing effort. *Am Rev Respir Dis* 1988; **138**:1169–1179.
- 13 Sassoos CS, Gruer SE. Characteristics of the ventilator pressure- and flow-trigger variables. *Intensive Care Med* 1995; **21**:159–168.
- 14 Kondili E, Prinianakis G, Georgopoulos D. Patient-ventilator interaction. *Br J Anaesth* 2003; **91**:106–119.
- 15 Susan P, Cairo JM. The Trigger variable. In *Mechanical ventilation physiological and clinical applications*. 4th ed. Philadelphia: Elsevier; 2006. 50–60.
- 16 Branson RD. Flow triggering systems. *Respir Care* 1994; **39**:892–896.
- 17 Polese G, Massara A, Poggi R, Brandolese R, Brandi G, Rossi A. Flow-triggering reduces inspiratory effort during weaning from mechanical ventilation. *Intensive Care Med* 1995; **21**:682–686.
- 18 Macnee W. Respiratory failure. In: Seaton A, Seaton D, Leitch AG, (editors) *Crofton and Douglas's respiratory diseases*. 5th ed. 2000; **24**:696–717.
- 19 Riker RR, Picard JT, Fraser GL. Prospective evaluation of the Sedation-Agitation Scale for adult critically ill patients. *Crit Care Med* 1999; **27**:1325–1329.
- 20 Corrado A, Ginanni R, Vilella G, Gorini M, Augustynen A, Tozzi D, et al. Iron lung versus conventional mechanical ventilation in acute exacerbation of COPD. *Eur Respir J* 2004; **23**:419–424.
- 21 Goulet R, Hess D, Kacmarek RM. Pressure vs flow triggering during pressure support ventilation. *Chest* 1997; **111**:1649–1653.
- 22 Sassoos CS, Giron AE, Ely EA, Light RW. Inspiratory work of breathing on flow-by and demand-flow continuous positive airway pressure. *Crit Care Med* 1989; **17**:1108–1114.
- 23 Giuliani R, Mascia L, Recchia F, Caracciolo A, Fiore T, Ranieri VM. Patient-ventilator interaction during synchronized intermittent mandatory ventilation. Effects of flow triggering. *Am J Respir Crit Care Med* 1995; **151**:1–9.
- 24 Correa TD, Passos RH, Kanda S, Taniguchi C. Flow or pressure triggering during pressure support ventilation? *Critical Care* 2007; **11**:P65.
- 25 Tantucci C, Duguet A, Giampiccolo P, Similowski T, Zelter M, Derenne JP. The best peak expiratory flow is flow-limited and effort-independent in normal subjects. *Am J Respir Crit Care Med* 2002; **165**:1304–1308.
- 26 Branson RD, Campbell RS, Davis K Jr, Johnson DJ II. Comparison of pressure and flow triggering systems during continuous positive airway pressure. *Chest* 1994; **106**:540–544.
- 27 Ranieri VM, Mascia L, Petruzzelli V, Bruno F, Brienza A, Giuliani R. Inspiratory effort and measurement of dynamic intrinsic PEEP in COPD patients: effects of ventilator triggering systems. *Intensive Care Med* 1995; **21**:896–903.
- 28 Nava S, Ambrosino N, Bruschi C, Confalonieri M, Rampulla C. Physiological effects of flow and pressure triggering during non-invasive mechanical ventilation in patients with chronic obstructive pulmonary disease. *Thorax* 1997; **52**:249–254.
- 29 Forte DN, Ranzani OT, Stape N, Taniguchi LU, Toledo-Maciel A, Park M. APACHE II and SOFA scores for intensive care and hospital outcome prediction in oncologic patients. *Critical Care* 2007; **11**:93.
- 30 Sassoos CS, Del Rosario N, Fei R, Rheeman CH, Gruer SE, Mahutte CK. Influence of pressure- and flow-triggered synchronous intermittent mandatory ventilation on inspiratory muscle work. *Crit Care Med* 1994; **22**:1933–1941.