The Effect Of The Trigger Variable On The Ineffective Triggering Index In Mechanically Ventilated Patients

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Abstract: Ineffective triggering of a ventilator-delivered breath may occur in as many as one-third of inspiratory efforts. There is a considerable and growing interest in optimizing the patient-ventilator interaction. The ineffective triggering is the commonest form of patient-ventilator dyssynchrony. The aim of this study was To determine the correlation between high rates of ineffective triggering within the first 24 hours of mechanical ventilation with the duration of mechanical ventilation and ventilator free survival and to study the effect of the trigger variable on the ITI (Ineffective Triggering index) in mechanically ventilated patients. The study was carried out on 150 mechanically ventilated adult patients in Alexandria University Main Hospital (EGYPT). Patients undergo a 10-minutes observation period within the first 24 hours of mechanical ventilation to identify (ITI) (=number of ineffective breaths/number of total breaths). The number of days on mechanical ventilation out of 28 days in the pressure triggering group was 6.89 ± 5.73 with ITI < 10% while it was 17.44 ± 9.0 with ITI ≥10% ($Z = 4.954^{*}$, $p < 0.001^{*}$) while the results in the flow triggering group was 8.10 ± 6.87 with ITI < 10% while it was 14.29 ± 9.11 with ITI ≥10% ($Z = 3.180^{*}$, $p = 0.001^{*}$). The ITI < 10% in pressure triggering group was 36/75 (48%) while 39/75 (52%) had ineffective triggering ≥10%. The ITI < 10% in flow triggering group was 41/75(54.7%) while 34/75 (45.3%) had ineffective triggering with no significant statistical difference between the 2 groups ($x^2 = 0.667$, $p = 0.414$). We conclude that the number of days on mechanical ventilation out of 28 days was significantly higher with ITI ≥10%.
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1. Introduction

All ventilators measure one or more variables associated with the equation of motion (i.e., pressure, volume, flow, or time). Inspiration is started when one of these variables reaches a preset value. Thus the variable of interest is considered an initiating, or trigger, variable. Pressure is the trigger variable when the ventilator senses a drop in baseline pressure caused by the patient's inspiratory effort and begins a breath. Flow is the trigger variable when the ventilator senses the patient's inspiratory effort in the form of flow of volume into the lungs.[1]

For the most effective unloading of the inspiratory muscles, the ventilator should cycle in synchrony with the patient's central respiratory rhythm. The interplay between the ventilator and the respiratory neuromuscular apparatus is complex, and problems can arise at several points in the respiratory cycle especially with triggering.[2]

Patient-ventilatory asynchrony exists if the phases of breath delivered by the ventilator do not match that of the patient. It can cause dyspnea, increase the work of breathing, patient discomfort and prolong the duration of mechanical ventilation. It can be detected by careful observation of the patient and examination of the ventilator waveforms. [3]

Ineffective triggering of a ventilator-delivered breath occur in as many as one-third of inspiratory efforts. It is accentuated by an insensitive inspiratory trigger, higher levels of pressure support, higher tidal volumes, and higher pH. The problem can be lessened by increasing the duration between the end of inspiration and the beginning of expiration with an end-inspiratory pause.[4]

There is a considerable and growing interest in optimizing the patient-ventilator interaction. The ineffective triggering is the commonest form of patient-ventilator dyssynchrony accounting for more than 80% of asynchronous breathes. It is frequently observed in intubated COPD patients with dynamic hyperinflation. A number of mechanisms have been associated with the development of ineffective triggering. It may occur because of intrinsic patient factors, including dynamic hyperinflation, reduced respiratory drive, or decreased respiratory muscle strength. It may also occur as a result of how the ventilator is set, including an insensitive trigger setting, excessive delivered minute ventilation, or increase pressure support level.[5]

The aim of this study was To determine the correlation between high rates of ineffective triggering within the first 24 hours of mechanical ventilation with the duration of mechanical ventilation and ventilator free survival and to study

the effect of the trigger variable on the ITI (Ineffective Triggering index) in mechanically ventilated patients.

2. Material and Methods

This study was carried out on 150 mechanically ventilated adult patient of both sex. The patients were selected from those who were admitted to the department of critical care medicine at Alexandria University Main Hospital.

The patients were classified into two groups according to their trigger variable: Group (A): patients on pressure triggering and Group (B): patients on flow triggering. Exclusion criteria were age less than 18, PEEP >10, oxygenation index less than 150 and patients unable to initiate breaths.

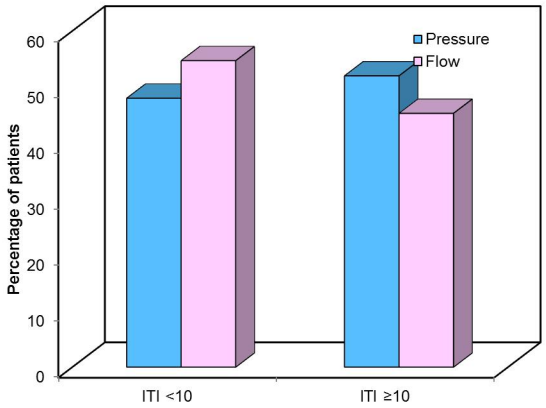
All patients in the study were subjected to thorough history taking, complete physical examination, radiological and laboratory investigations relevant to their condition as well as recording of the reason of mechanical ventilation and the details of the ventilator setting.

Identifying asynchrony was noticed as a Simultaneous decrease in airway pressure and an increase in airflow without assisted ventilatory cycle. All Patients underwent a 10-minutes observation period within the first 24 hours of mechanical ventilation. During an observation period, pressure-time and flow-time waveforms were observed to identify ineffective triggering. Ineffective triggering index was calculated for patients: (ITI = $\frac{\text{number of ineffective triggers}}{\text{number of total breathes}}$)

The primary end point was the number of days on mechanical ventilation out of 28 days and 28-days ventilator-free survival between patients with ITI ≥ 10% and those with ITI < 10%. The effect of the triggering method (flow versus pressure) on ITI was compared between the two groups. Re-intubation number, Tracheostomy number, ICU mortality number were recorded as determinants of the patients' outcome.

3. Results

The ineffective triggering index (ITI) for the patients in the pressure group was less than 10% in thirty six patients (48%), and more than 10% in thirty nine patients (52%), while in the flow group the ITI was less than 10% in forty one patients (54.7%), and more than 10% in thirty four patients (45.3%).When the 2 groups were compared to each other, no significant difference was detected in the ineffective triggering index. (Table 1 & figure1)



Ineffective triggering index (ITI) in the two groups of patients (figure 1)

The number of days on mechanical ventilation out of 28 days for the patients in the pressure group with an ITI <10% ranged from 1.0 – 28.0 days with a mean of 6.89 ± 5.73 days and for the patients with an ITI >10 in the pressure group it ranged from 1.0 – 28.0 days with a mean of 17.44 ± 9.0 days ; while for the patients in the flow group with an ITI <10% ranged from 1.0 – 28.0 days with a mean of 8.10 ± 6.87 days and for the patients with an ITI >10 in the flow group it ranged from 1.0 – 28.0 days with a mean of 14.29 ± 9.11 days. There was a statistically significant difference between the number of days on mechanical ventilation out of 28 days in both the pressure group and the flow group for those patients with an ITI less than 10% and the patients with an ITI more than 10% (p <0.001 for both of them). No statistically significant difference was found while comparing the patients with an ITI less than 10% in both the pressure and the flow groups (p = 0.500) or while comparing the patients with an ITI more than 10% in both the pressure and the flow groups (p = 0.142) (table2)

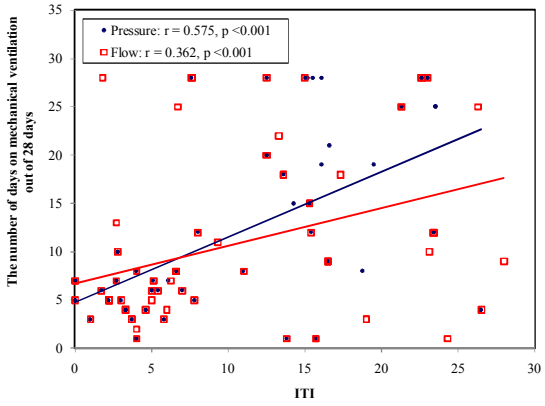
Twenty eight days ventilator-free survival (VFS) for the patients in the pressure group with an ITI <10% ranged 0.0 – 25.0 days from with a mean of 16.08±9.58 days of and for the patients with an ITI >10 in the pressure group it ranged 0.0 – 19.0 days from with a mean of 4.21 ± 6.60 days ; while for the patients in the flow group with an ITI <10% ranged from 0.0 – 26.0 days with a mean of 16.37 ±9.88 days and for the patients with an ITI >10 in the flow group it ranged from 0.0 – 19.0 days with a mean of 5.32 ± 7.61 days. There was a statistically significant difference between 28-days ventilator-free survival in both the pressure group and the flow group for those patients with an ITI less than 10% and the patients with an ITI more than 10% in both groups (p <0.001 for both of them). (Table 2)

The Re-intubation for the patients in the pressure group with an ITI <10% occurred in four patients (11.1%) of and for the patients with an ITI >10 in the pressure group it occurred in fourteen patients(35.9%) which was statistically significant difference between the two groups of patients (p=0.015) ; while for the patients in the flow group with an ITI <10% re-intubation occurred in seven patients(17.1%) and for the patients with an ITI >10 in the flow group it occurred in nine patients(26.5%) , but no statistically significant difference between groups. (Table 3)

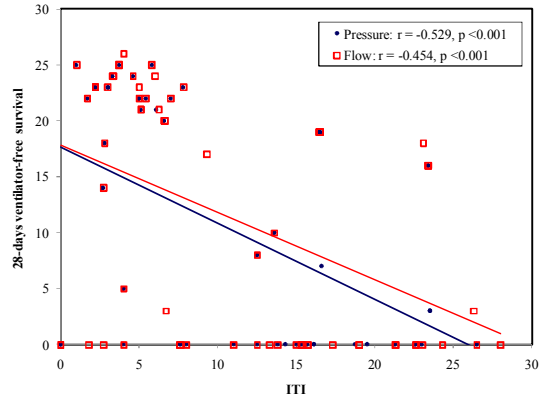
The tracheostomy number for the patients in the pressure group with an ITI <10% was four patients (11.1%) of and for the patients with an ITI >10 in the pressure group it was in twenty patients(51.3%) which was statistically significant difference between the two groups of patients (p<0.001) ; while for the patients in the flow group with an ITI <10% tracheostomy was done in five patients(12.2%) and for the patients with an ITI >10 in the flow group it occurred in ten patients (29.4%) , but no statistically significant difference between the 2 groups was found. (Table 3)

ICU mortality number for the patients in the pressure group with an ITI <10% was eleven patients (30.6%) of and for the patients with an ITI >10 in the pressure group it was in twenty four patients (61.5%) which was statistically significant difference between the two groups of patients (p = 0.007) ; while for the patients in the flow group with an ITI <10% eleven patients (26.8%) died and for the patients with an ITI ≥10% in the flow group nineteen patients (55.9%) died, and statistically significant difference was also found (p=0.011). (table 3)

Correlation tests between the ITI and different parameters were done and the following results were found: Significant positive correlation was found between the ITI and the number of days on mechanical ventilation out of 28 days of the patients in both the studied groups (Figure 2). Significant negative correlation was found between the ITI and the 28-days ventilator-free survival of the patients in both the studied groups (Figure 3). Positive correlation was found between the ITI and the Re-intubation number of the patients in both groups although it was statistically significant only in the pressure group. Positive correlation was found between the ITI and the reintubation and Tracheostomy number of the patients in both groups although it was statistically significant only in the pressure group. Positive correlation was found between the ITI and the ICU mortality number of the patients in both groups although it was statistically non-significant in both of the studied groups.



Correlation between ITI and number of days on mechanical ventilation (figure 2)



Correlation between ITI and 28-days ventilator free survival (figure3)

Table 1. Ineffective triggering index (ITI) in the two groups of patients

	Pressure group n = 75	Flow group n = 75	Test of sig.
ITI number (%):			
<10	36 (48.0%)	41 (54.7%)	$\chi^2 = 0.667$
≥10	39 (52.0%)	34 (45.3%)	p = 0.414

χ^2: Chi square test ; Z : Z for Mann Whitney test

Table 2. Comparison between patients with an ITI<10% and patients with an ITI≥10 and the number of days on mechanical ventilation out of 28 days, 28-days ventilator-free survival in the two studied groups

	ITI			
	Pressure (n = 75)		Flow (n = 75)	
	<10	≥10	<10	≥10
The number of days on mechanical ventilation out of 28 days:				
Range	1.0 – 28.0	1.0 – 28.0	1.0 – 28.0	1.0 – 28.0
Mean ± SD	6.89 ± 5.73	17.44 ± 9.0	8.10 ± 6.87	14.29 ± 9.11
Test of sig.	Z = 4.954*, p <0.001		Z = 3.180*, p < 0.001	
Test of sig.			Z = 0.674 p = 0.500	Z = 1.470 p = 0.142
28-daysventilator-free survival:				
Range	0.0 – 25.0	0.0 – 19.0	0.0 – 26.0	0.0 – 19.0
Mean ± SD	16.08±9.58	4.21 ± 6.60	16.37 ±9.88	5.32 ± 7.61
Test of sig.	Z = 5.110*, p <0.001		Z = 4.883*, p <0.001	

Z : Z for Mann Whitney test; * : Statistically significant at $p \leq 0.05$

Table 3. Comparison between patients with an ITI<10% and patients with an ITI≥10 regarding re-intubation, tracheostomy and ICU mortality in the two studied groups

	ITI			
	Pressure (n = 75)		Flow (n = 75)	
	<10	≥10	<10	≥10
Re-intubation number (%):				
No	32 (88.9)	25 (64.1)	34 (82.9)	25 (73.5)
Yes	4 (11.1)	14 (35.9)	7 (17.1)	9 (26.5)
Test of sig.	FEp = 0.015*		FEp = 0.978, p = 0.323	
Tracheostomy number (%):				
No	32 (88.9)	19 (48.7)	36 (87.8)	24 (70.6)
Yes	4 (11.1)	20 (51.3)	5 (12.2)	10 (29.4)
Test of sig.	FEp <0.001*		FEp = 3.443, p = 0.064	
ICU mortality number (%):				
No	25 (69.4)	15 (38.5)	30 (73.2)	15 (44.1)
Yes	11 (30.6)	24 (61.5)	11 (26.8)	19 (55.9)
Test of sig.	χ^2 = 7.220*, p = 0.007		χ^2 = 6.537*, p = 0.011	

χ^2: Chi square test ; FEp : p value for Fisher Exact test; * : Statistically significant at $p \leq 0.05$

4. Discussion

Over the past 10 to 15 years, much insight has been gained into the behavior of critically ill patients undergoing mechanical ventilation. One of the main clinical implications derived from relevant studies is that respiratory muscle exertion may be substantial despite application of ventilatory support.[6]

Among the major factors shown to influence inspiratory effort during assisted forms of ventilation is the effort required to trigger the ventilator. The widespread introduction of pressure-triggered demand valves on most mechanical ventilators prompted several studies which demonstrated that such systems imposed more work of breathing (WOB) than traditional continuous-flow systems.[7]Flow triggering has usually been associated with a reduction in breathing effort as compared with pressure triggering (PT), although a significant benefit was not found consistently in all studies[8-11]

This was in agreement of our study as there was no significant difference between flow and pressure triggering. To our knowledge our study is the first to study the effect of pressure Versus flow triggering on the patient-ventilator dys-synchrony namely the ineffective triggering index.

In our study we used the ineffective triggers as an indicator for the degree of patient synchrony with the ventilator. Ineffective triggers with a cut off limit of 10% was selected during this study, as it was used in another study by de Wit et al.[12]

We found a strong association between the ineffective triggering and poor outcome as evidenced by increased number of days on mechanical ventilation, decreased ventilator free survival, increased incidence of Re-intubation, number of tracheostomised patients and increased ICU mortality. We found that the patients with an ITI ≥ 10% in both the pressure and the flow groups stayed longer on mechanical ventilation, compared to those with an ITI < 10%. Also the duration that the patients

spent while being disconnected from mechanical ventilation i.e. successful weaning (28 days-ventilator free survival) was lesser in those patients with an ITI ≥ 10% compared to those with an ITI < 10% in both the pressure and the flow groups and Significant positive correlation was found between the ITI and the number of days on mechanical ventilation out of 28 days of the patients and between the ITI and the 28-days ventilator-free survival of the patients in both the studied groups.

Comparable with our findings; previous studies have also found an association between ineffective triggering and poor outcome. Chao et al[13] have studied 174 ventilator dependent patients and demonstrated that patients with ineffective triggering required longer duration of mechanical ventilation (70 vs. 33days) and had lower rate of successful weaning (16% vs. 57%) compared to those without ineffective triggering. Thille et al[14] also demonstrated that patients with high rates of asynchrony experience longer duration of mechanical ventilation(25 Vs 7 days), increased rate of tracheostomy (33% Vs 4 %) but no difference in mortality. our findings are like those of these investigators by finding that an ineffective triggering index ≥10% detected in the 1st 24 hours of mechanical ventilation is associated with prolonged duration of mechanical ventilation and increased length of stay, we found also a statistical difference in mortality.

Our study revealed an association between high rate of ineffective triggering and mechanical ventilation outcome but doesn't allow determination of cause and effect, our study like those of Thille[14], Chao[13], and de Wit[12] doesn't answer whether ineffective triggering is the cause of prolonged mechanical ventilation or merely a marker of poor outcome. Although we can't rule out the latter; a multivariate analysis that was done by de Wit et al[100] suggested that ineffective triggering could contribute to poor outcome through several mechanisms , by increasing the work of breathing, ineffective triggering could predispose to respiratory muscles fatigue or injury, limiting subsequent attempts to liberate the patient from mechanical ventilation, alternatively a failure to detect the presence of ineffective respiratory efforts may lead to erroneous conclusion about a patient's readiness for or tolerance of spontaneous breathing trials.

Purro et al[15] have shown that failure to account for ineffective efforts leads to an underestimation of the frequency tidal volume ratio. A falsely low frequency tidal volume ratio could lead to premature trials of spontaneous breathing. In contrast a reduction in ventilator support leads to conversion of ineffective to effective (e.g. ventilator measured) breaths, even though the patient's actual respiratory rate (ineffective plus effective) remains unchanged.[16] The apparent increase in respiratory rate (as determined from the ventilator display) may be erroneously attributed to intolerance for spontaneous breathing. Lastly patient-ventilator asynchrony may disrupt sleep quality which could adversely affect outcome.[17]

Our study has several limitations. Although we used a well-defined time frame , the 1st 24 hours of mechanical ventilation , we analyzed only discrete 10 minutes segment during that period therefore we may have underestimated the prevalence of ineffective triggering along these lines. It's possible that some of our patients demonstrated transient ineffective triggering where as others manifested sustained asynchrony. Another limitation is that our method didn't allow us to define the etiology for ineffective triggering for a given patient.

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