Value of Automatic Tube Compensation during Weaning of Mechanically Ventilated Patient in Medical Intensive Care Unit

Mohamed Abouzeid.¹, Ahmed E. Kabil.², Ahmed Al-Ashkar ¹ and Hafez A. Abdel-Hafeez¹ ¹Department of Internal Medicine, Faculty of Medicine, Al-Azhar University, Cairo, Egypt ²Department of Chest diseases, Faculty of Medicine, Al-Azhar University, Cairo, Egypt muhamedabozeid@gmail.com,a_ka_81@yahoo.com,dr_alashkar@yahoo.com

Abstract: Background: Automatic tube compensation (ATC) is recently developed to compensate for artificial airway resistance which may be beneficial during spontaneous breathing trials. It is used as a mode of mechanical ventilation in some newer mechanical ventilators and as an add-on feature for existing ventilation modes in some other ventilators **Objective:** To assess the expected benefit of ATC in improving the weaning process . Patients and methods: A prospective randomized controlled trial conducted at Medical Intensive Care Unit of Al-Hussein University Hospital. 60 mechanically ventilated patients were included during the period from September 2016 to June 2017 .Patients were randomly divided into three groups, 20 patients weaned by pressure support ventilation (PSV) plus ATC, 20 patients weaned by pressure support ventilation (PSV) and 20 patients weaned by ATC. The primary outcomes measure was weaning outcomes and duration. A total of 60 patients were included; the mean **Results**: ages for groups were (59.800±5.1667,60.500±4.5480,59.500±3.9537 years), The weaning duration of PSV plus ATC group was significantly lower than other groups. The duration of weaning in ATC group was lower than PSV group. There was a higher trend towards Successful extubation in PSV plus ATC group than other groups but without statistically significant difference. Mortality and morbidity were lower in PSV plus ATC group than other groups and were lower in ATC group than PSV group but without statistically significant difference. **Conclusion**: In Medical ICU patients, the weaning process can be successfully performed by ATC as an add-on feature to existing modes or as a separate mode but without significant hastening of the weaning. Some outcomes were potentially improved (duration of ICU stay, total duration of mechanical ventilation and weaning duration).

[Mohamed Abouzeid., Ahmed E. Kabil., Ahmed Al-Ashkar and Hafez A. Abdel-Hafeez] 1. Value of Automatic Tube Compensation during Weaning of Mechanically Ventilated Patient in Medical Intensive Care Unit]

Keywords: automatic tube compensation, pressure support ventilation, medical ICU, weaning. [Mohamed Abouzeid., Ahmed E. Kabil., Ahmed Al-Ashkar and Hafez A. Abdel-Hafeez] **Value of Automatic Tube Compensation during Weaning of Mechanically Ventilated Patient in Medical Intensive Care Unit.** *N Y Sci J* 2017;10(5):82-89]. ISSN 1554-0200 (print); ISSN 2375-723X (online).

http://www.sciencepub.net/newyork. 12. doi:10.7537/marsnys100517.12.

1. Introduction

Weaning is the process of withdrawing mechanical ventilatory support, liberating the patient from the endotracheal tube and transferring the work of breathing from the ventilator to the patient. Weaning from mechanical ventilation (MV) is still a great challenge and its prolongation is related to increased mortality and morbidity(1) Recently, with the great advances in technology, new features on ventilators have been developed as automatic tube compensation (ATC). Several trials have been done to evaluate weaning outcome using either this new mode or add-on feature to traditional modes with a promising results (2–5). With the flow of air through the tube there will be a difference in pressure between the two ends of the tube and the patients respiratory muscles have to compensate for this pressure difference especially during spontaneous breathing . ATC is based on continuous calculations of tracheal pressure difference between the two ends of the tube This calculation is based on continuous

and regular measurement of air flow, airway pressure (at both ends of the tube) and tube specific co-efficient (6). ATC works to compensate for the pressure difference across the tube by delivering the exact amount of pressure necessary to overcome this resistive load (7). On the other hand, tube obstruction as a result of secretions or kinking may cause under compensated tube resistance with the ATC (8.9). In many studies ATC has been shown to decrease the work of breathing(WOB) used to overcome the resistive load of ETT more effectively than traditional methods of weaning as pressure support ventilation It is assumed that it can simulate (PSV). spontaneous breathing without ETT, so it is 'electronic extubation'. sometimes called So, ATC is ideally suitable for use during spontaneous breathing trial during the weaning process (10). Therefore, ATC may decrease the weaning period and increase the probability of successful extubation (11).

The aim of the study was to evaluate the value of ATC either as a mode ventilation or as an add-on feature to other modes in the process of weaning.

2. Patients and methods

This prospective randomized controlled study was conducted from September 2016 to June 2017, in the Medical Intensive Care Unit of Al-Hussein University Hospital. The study included 60 mechanically ventilated patients. An informed written consent was taken from the first degree relative of every patient included in the study & the study was approved by the Ethics Committee For Research Of Faculty Of Medicine, Al-Azhar University.

Inclusion criteria:

Adult patients who were endotracheally intubated, undergoing mechanical ventilation for at least 24 h and ready for SBT, with the intention of discontinuing mechanical ventilation according to our MICU's ventilator weaning protocol according the current statement of **ERS, ATS, ESICM, SCCM and SRLF** (12).

Exclusion criteria: Age < 18 years, Pregnancy, Unplanned extubation either during or before the weaning process, Death before becoming ready to wean or patients who completed 7 days of mechanical ventilation without fulfilling weaning criteria.

Initiation of mechanical ventilation

All included patients were intubated with endotracheal tube size 7 to 8. Mechanical ventilation performed using **Dräger Evita V 300** Patients were adjusted on Synchronized Intermittent Mandatory Ventilation (SIMV), volume controlled mode except for cases with Adult Respiratory Distress Syndrome (ARDS) where pressure controlled ventilation was used with lung protective strategy.

All patients were receiving standard medical therapy . Sedation was achieved with midazolam and tailored for each individual patient according to his or her need and stopped when the patient was ready for weaning.

Weaning was decided when the patients became ready for weaning after achievement of the weaning criteria according the current statement of **ERS, ATS, ESICM, SCCM and SRLF** (12). patients will be randomly divided into three groups; Group (I) included 20 patients who were weaned by automatic tube compensation with pressure support.(PSV+ATC),Group (II) included 20 patients who were weaned by pressure support ventilation alone (PSV), Group (III) included 20 patients who were weaned by automatic tube compensation (ATC) alone.

The weaning protocol for the three groups:

weaning from MV was considered as early as possible. Patients underwent a daily screen for assessment of readiness to wean . SBT was conducted early in the morning. The duration of the trials ranges between 30 and 120 min. The SBT was performed with either PSV, ATC or PSV plus ATC. In all groups, the ventilator parameters were adjusted as the following: flow-triggering set at 3 1/min, the peak end expiratory pressure at 0-5 cmH2O and FiO2 less than or equal to 0.4. For the patients weaned by PSV only (20 patients), initial positive pressure support (PS) was 15 cmH2O. Extubation was done at PS of 8 cmH2O, resistance. PS was which is equal to tube gradually lowered by 2-4 cmH2O . In the ATC group (20 patients), the size of the ETT is entered into the *ventilator software and inspiratory ATC set at 100%. Pressure support was adjusted at zero (the type of ventilators used in current study has only ATC as add-on feature to other modes, so we used PS with ATC and set PS at zero to equal ATC mode only in other types of ventilators) and PEEP was 0-5 cmH2o. In the PSV plus ATC group (20 patient), initial positive pressure support (PS) was 15 cmH2O. Patients were extubated at PS of 8 cmH2O in the same situation the size of the ETT is entered into the ventilator software and inspiratory ATC set at 100%. Patients who failed the first SBT underwent all subsequent SBTs with the same SBT method.

Patients were observed for dyspnea, fatigue, anxiety, and distress during SBT. The criteria for successful SBT include good respiratory pattern, efficient gas exchange, hemodynamic stability, and patient comfort (12). Mechanical ventilation (by the same mode) was returned with any of the following: Tachypnoeic (Respiratory rate ≥ 35 breaths/min), Desaturation (oxygen saturation < 90%.), Heart rate >140 beats/min or a sustained increase or decrease in the heart rate of more than 20% of that before starting weaning. Systolic blood pressure < 90 mmHg or > 180 mmHg, Agitation or diaphoresis, Hypercapnia with increased level of $PaCO2 \ge 20\%$ from the previous value. deterioration of the neurological status, including psychomotor agitation (13).

Weaning success: defined as independence from mechanical ventilation (either invasive or non-invasive) \geq 48 hours after extubation., **Weaning failure**: was considered with any one of the following: Failure of spontaneous breathing trials, Re-intubation and/or resumption of MV within 48 hours of extubation, Death within 48 hours of extubation(13).

Length of ICU or hospital stay: the time from admission to the ICU or the hospital until discharge or death., Complications related to MV: such as, VAP, pneumothorax & tracheostomy

The following data were collected from all groups to be statistically analyzed and

compared: Demographic data (age, sex & BMI) ,APACHII, Hemodynamic parameters (heart rate, respiratory rate and mean arterial blood pressure) before randomization & before successful extubation, Ventilator parameters 1 hour after randomization & before successful extubation (FIO2, peak airway pressure, VT, RR, minute ventilation & auto-PEEP)which were considered as the mean of three successive breath cycles at least. Arterial blood gases (ABGs) before randomization, one hour after randomization & before successful extubation, Duration of weaning, Duration of mechanical ventilation, Length of ICU stay, Length of hospital stay, Complications: including VAP, pneumothorax, arrhythmia, tracheostomy, reintubation & deaths.

Statistical Analysis The collected data was organized, tabulated and statistically analysed using SPSS software statistical computer package Та

version 16. For qualitative data, frequency and percent of distribution were calculated and for comparison between groups, chi-square test was used. For quantitative data, mean, standard deviation (SD) and sometimes, median, minimum and maximum were calculated. The (one way Anova test) was used for comparison between normally distributed quantitative variables, and when P-value ≤ 0.05 (Tukey-Kramer test) was used groups., for multiple comparison between (Kruskal-Wallis non-parametric test) was used for comparison between abnormally distributed quantitative variables, and when P-value ≤ 0.05 , (Dunn's multiple comparisons test) was used for multiple comparisons between groups. For interpretation of results, p-value ≤ 0.05 was considered statistically significant

3. Results

able	(1): Demographic data	and baseline	difference between	the studied groups:

Groups	PSV+ATC	PSV	ATC	ANOVA
				P-value
Age	59.800±5.1667	60.500±4.5480	59.500±3.9537	.779
_				
Male	15	14	15	.918
	34.1%	31.8%	34.1%	
Female	5	6	5	. 918
	31.3%	37.5%	31.3%	
BMI	23.250±2.0995	24.700±1.8093	24.400±1.7592	.046
APACHE II	23.14±4.89	21.14±2.89	24.14±4.22	
				0.38

Continuous data are presented as mean \pm SD, whereas categorical variables are presented as frequency and %; APHCHE II, *Significant difference.

Table (2) Diagnosis of patients on ICU admission

Diagnosis	PSV+ATC	PSV	ATC	Total
Pneumonia	7	4	5	16
	43.8%	25.0%	31.3%	100.0%
Sepsis	3	4	3	10
	30.0%	40.0%	30.0%	100.0%
COPD exacerbation	5	3	4	12
	41.7%	25.0%	33.3%	100.0%
CNS CAUSE	4	6	5	15
	26.7%	40.0%	33.3%	100.0%
Pulmonary edema	1	3	3	7
-	14.3%	42.9%	42.9%	100.0%
P-value	.927	·	•	

Table (3): Vital signs and blood gases at the start of weaning trial

Groups	PSV+ATC	PSV	ATC	ANOVA
				P-value
Heart rate	82.900±6.0689	83.000±7.4763	87.000±5.6382	.080
Mean	89.950±6.3035	92.000±6.4400	92.500±6.0654	.401

19.050±2.7810	18.400±2.7415	20.350±2.0844	.057
.4175±.04667	.4125±.04552	.4100±.04757	.875
$7.3865 \pm .05575$	$7.3890 \pm .03782$	7.4145±.04371	.116
75.350±3.4985	73.450±4.9148	73.250±5.0667	.281
47.600±4.6611	49.050±5.6798	48.150±4.6597	.656
32.600±2.9451	31.500±4.0717	30.700±3.4808	.241
	.4175±.04667 7.3865±.05575 75.350±3.4985 47.600±4.6611	.4175±.04667 .4125±.04552 7.3865±.05575 7.3890±.03782 75.350±3.4985 73.450±4.9148 47.600±4.6611 49.050±5.6798	.4175±.04667 .4125±.04552 .4100±.04757 7.3865±.05575 7.3890±.03782 7.4145±.04371 75.350±3.4985 73.450±4.9148 73.250±5.0667 47.600±4.6611 49.050±5.6798 48.150±4.6597

ATC, automatic tube compensation; BP, blood pressure; PSV, pressure support ventilation.

Table (4): Comparison between the ventilatory parameters of studied groups one hour after weaning trial:

Parameter	PSV+ATC	PSV	ATC	ANOVA
				P-value
FIO2	.3825±.02447	.3750±.03804	.3950±.02763	.122
Respiratory rate)RR(20.700±2.3864	22.550±2.5438	21.650±2.4121	.066
Tidal volume)VT(.5280±.07431	.5860±.05124	.5795±.06863	.013
Peak inspiratory pressure (PIP)	19.550±2.1637	19.700±2.2029	21.550±1.9861	.006
Minute ventilation (MV)	8.825±1.4920	8.850±1.2185	8.955±1.5497	.954

Table (5): Comparison between the ABG parameters of studied groups one hour after weaning trial:

Parameter	PSV+ATC	PSV	ATC	ANOVA
				P-value
FIO2	.3675±.04064	.3725±.03432	.3950±.02763	.034
РН	7.3930±.02774	7.4145± .03561	7.4025 ±.03127	.108
PO2	82.800± 3.8471	80.550± 3.0689	80.100±2.7701	.025
PCO2	52.750±4.4114	50.350± 5.0915	51.100±4.6215	.266
HCO3	31.050±2.4382	32.000± 3.2767	30.100 ±2.5526	.106

4. Discussion

Automatic tube compensation (ATC) is a recently developed mechanical ventilatory support method to overcome the endotracheal tube resistance. It is used as a mode of ventilation in some ventilators while in others it is used as an add-on feature to other modes. Pressure support ventilation (PSV) is a common mode for providing support during weaning from mechanical ventilation. It generates pressure constant that а complements patient effort throughout the inspiratory period (14,15), In this prospective controlled trial, 60 patients were recruited in with the aim of the comparing automatic tube compensation with pressure support (PSV) in

weaning of different diseases, patients were divided into 3 groups: group (I) included 20 patients who were weaned by automatic tube compensation with pressure support. (PSV+ATC), group (II) included 20 patients who were weaned by pressure support alone (PSV), group (III) included 20 patients who were weaned by automatic tube compensation alone (ATC), All patients were ready for weaning after improvement of general conditions, gas exchange & respiratory acidosis. In the present study, there was no statistically significant difference in the age of the studied groups .Also, there was no statistically significant difference in gender distribution & BMI between studied groups, with predominant male gender in each group .

Table (6):	Weaning	course	and	outcome
-------------------	---------	--------	-----	---------

Parameter	PSV+ATC	PSV	ATC	Total	ANOVA		
	(n=20)	(n=20)	(n=20)	N=60	P-value		
Duration of MV	$2.875 \pm .5350$	3.125 ± 1.0867	3.050±.5356		.573		
(Days) before							
Weaning trial							

Duration of weaning (hours)	36.714± 21.5779	83.500±47.3142	54.000±29.0631			.004
Number of spontaneous breathing trials	1.800±.8944	2.000±.5620	1.750±.5620			.482
successful extubation after weaning trials	14 70%	12 60%	13 65%		.803	
Complications during weaning process(VAP)	4 %20	5 %25	4 % 20		1.000	
ICU mortality	4	5	4	13	.906	
Total duration of MV (Days)	4.464±.7712	6.750±1.3568	5.538± 1.2659			.005*
Duration of ICU stay (Days)	7.821±1.1026	9.208±1.7511	8.462± 1.1080			.041*
Duration of hospital stay (Days)	12.071±1.5915	13.500 ± 1.4460	13.000±1.6833			.076
Failure of first spontaneous breathing trials	1.5500±.51042	1.8500±.36635	1.7000±.47016		.121	
Number of spontaneous breathing trials	1.800±.8944	2.000±.5620	1.750±.5620		.482	

Moreover, there was no significant difference between the studied groups in mean APACHE II score at time of ICU admission or cause of mechanical ventilation.

In addition, there was no statistically significant difference in vital signs and arterial blood gases of the studied groups before starting weaning trial and randomization.

So, there were no significant differences in baseline characteristics between the studied groups . and we can suggest that the three methods of weaning ((PSV+ATC, PSV & ATC)) can be conveniently compared with each other in terms of weaning

progress and outcome and also length of stay, the occurrence of

complications, and mortality rate(5).

In the current study the ventilatory parameters of the studied groups one hour after randomization showed, statistically significant decrease in the peak inspiratory pressure (PIP) & the tidal volume (VT) of the PSV+ATC group than other groups. Apart from the peak inspiratory pressure and tidal volume, there was no statistically significant difference between the studied groups of the current study in other ventilatory parameters one hour after randomization. Also, The ABG parameters in the current study showed a statistically insignificant difference between studied groups one hour after randomization. These results are consistent with Figueroa-Casas et al. (2010) who posted that RR/TV ratio and Pao₂/Fio₂ had no significant difference between

ATC group and CPAP group. Selek et al. (2014) reported that no significant difference as regard respiratory rat and SaO_2 over the course of the study period between ATC and T-piece. On the other hand, *Haberthur et al.* (2002) stated that there were significant difference between both groups in respiratory rate, tidal volume and RR/TV ratio.

Before starting weaning in the current study, there was no statistically significant difference between the studied groups in the duration of mechanical ventilation . the weaning duration of PSV+ATC group was significantly lower than ATC group and that of ATC group was lower than PSV group (but statistically insignificant).

In agreement with our results, *Aggarwal et al.* (2009) concluded that duration of weaning was significantly shorter in the PSV plus ATC group than in the PSV group in patients with severe neuroparalytic snake envenomation.

In addition ,*Figueroa-Casas et al. (2010)* reported non-significant trend toward shorter duration of weaning trials with ATC than PSV.

Also, *Selek et al. (2014)* found weaning duration was significantly shorter in ATC versus T-piece.

Despite significant shortening in the duration of mechanical ventilation of PSV+ATC group than ATC & PSV groups in the current study, the length of ICU stay & the duration of hospital stay did not differ

significantly among studied groups

. In the current study, weaning success was achieved in 14 patients

(70%) of PSV+ATC group, 13 patients (65%) of ATC group & 12 patients (60%) of PSV group, without statistically significant difference among studied groups in the outcome of weaning.

Comparable to the results of the present study, **El-Shahat, et al., 2014** who studied 166 mechanically ventilated patients ready for weaning, Comparing ATC mode with PSV mode: was no statistically significant difference between studied groups in weaning success where was achieved in 69 patients (78.4%) of PSV & 69 patients (88.5%) of ATC group, without statistically significant difference among studied groups in the outcome of weaning. Also these results were consistent with **Haberthur and colleagues**, and **Figueroa-Casas and colleagues**,

who concluded nearly the same result with different numbers.

Mortality and morbidity were lower in PSV plus ATC group than other groups and were lower in ATC group than PSV group. However, there was no statistically significant difference among studied groups of the current study in the rate of mortality

Financial support and sponsorship Nil. **Conflicts of interest**

There are no conflicts of interest

References

1- Chang DW & Hiers JH. (2013b): Weaning from mechanical ventilation. In: Clinical applications of mechanical ventilation fourth Edition. Chang DW, United States of America. Delmar Cengage learning, Chapt. 16, p. 516-536

Cohen JD, Shapiro M, Grozovski E, Singer P. Automatic tube compensation-assisted respiratory rate to tidal volume ratio improves the prediction of weaning outcome. Chest 2002; 122:980–984.
 Cohen JD, Shapiro M, Grozovski E, Lev S, Fisher H, Singer P. Extubation outcome following a spontaneous breathing trial with automatic tube compensation versus continuous positive airway pressure. Crit Care Med 2006; 34:682–686.

4- Cohen J, Shapiro M, Grozovski E, Fox B, Lev S, Singer P. Prediction of extubation outcome: a randomised, controlled trial with automatic tube compensation vs. pressure support ventilation. Crit Care 2009;13:R21.
5- Selek C, Ozcan PE, Orhun G, Şenturk E, Akinci IO, Cakar N The comparison of automatic tube compensation (ATC) and T-piece during weaning. Turk J Anaesth Reanim 2014; 42:91–95.

6- Haberthur C, Mols G, Elsasser S, Bingisser R, Stocker R, Guttmann J. Extubation after breathing trials with automatic tube compensation, T-tube, or pressure support ventilation. Acta Anaesthesiol Scand 2002; 46:973–979.

7- Frutos-Vivar F, Esteban A. Weaning from mechanical ventilation:why are we still looking for alternative methods? Med Intensiva 2013;37:605–617.

8- Haberthur C, Mols G, Elsasser S, Bingisser R, Stocker R, Guttmann J.Extubation after breathing trials with automatic tube compensation,T-tube, or pressure support ventilation. Acta Anaesthesiol Scand 2002; 46:973–979.

9- Oto J, Imanaka H, Nakataki E, Ono R, Nishimura M. Potential inadequacy of automatic tube compensation to decrease inspiratory work load after at least 48 hours of endotracheal tube use in the clinical setting. Respir Care 2012; 57:697–703.

10- Eskandar N, Apostolakos MJ. Weaning from mechanical ventilation. Crit Care Clin 2007; 23:263–274.

11- Aggarwal AN, Agarwal R, Gupta D. Automatic tube compensation as

an adjunct for weaning in patients with severe neuroparalytic snake envenomation requiring mechanical ventilation: a pilot randomized study.Respir Care 2009; 54:1697–1702.

12-Boles JM, Bion J, Connors A, Herridge M, Marsh B, Melot C, Pearl R & Silverman H. (2007): Weaning from mechanical ventilation. Eur Respir J 2; 29:1033–56

and the complications related to mechanical ventilation. These results are consistent with **El-Shahat and colleagues** who concluded a non-significant decrease in mortality and complications with ATC.

The main limitations of our study are low number of patients included and it was a single center study.

So large multi-centers studies are recommended for further evaluation of ATC either add-no feature or a separate mode in the process of weaning of mechanically ventilated patients.

Conclusion:

According to the current study results, we can conclude that in a medical ICU population, ATC (either as add-on feature or as a separate mode) was safe, efficient, and can be successfully used for weaning. It has a potential benefit in weaning duration, extubation outcome, ICU length of stay, complications, and mortality rate. So, ATC may be a valuable add-on feature or mode for use during the process of weaning of mechanically ventilated patients. 13- Boles JM, Bion J, Connors A, et al. Weaning from mechanical ventilation. Eur Respir J. 2007;29(5):1033-1056.

14- Prakash P, Krishna K & Singh P. (2007): Weaning Modes in Mechanical Ventilation. JIACM; 8(3): 222-5.

15- Prakash P, Krishna K, & Bhatia D. (2006): Complications of Mechanical Ventilation. Journal, Indian Academy of Clinical Medicine, 7(3).

16- Figueroa-Casas JB, Montoya R, Arzabala A, Connery SM. Comparison between automatic tube compensation and continuous positive airway pressure during spontaneous breathing trials. *Respir Care* 2010; **55**:549–554.

17- El-Shahat H, Salama S, Wafy S, Bayoumi H.(2015): Automatic tube compensation versus pressure support ventilation as a weaning mode: does it make a difference?. *Egypt J Broncho* 2015 9:253–260.