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Original article

Role of Capnography in Weaning in Mechanically Ventillated COPD Patients

Walaa Y. El-Desoky [a], Yousry E. Rezk [a], Basem M. Aglan [a], Mohamed s. sadek [b]

[a] Cardiothoracic Department, Faculty of Medicine Benha University, Egypt.

[b] Chest Diseases Department, Faculty of Medicine Benha University, Egypt.

Corresponding to:
Dr. Walaa Y. El-Desoky.
Cardiothoracic Department, Faculty of Medicine Benha University, Egypt.

Email:
walaayahia510@gmail.com

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Abstract:

Background: Capnography has made steady inroads in the ICU and is increasingly used for all patients who are mechanically ventilated. There is growing recognition that capnography is rich in information about lung and circulatory physiology and provides insight into many diseases and treatments. **Aim and objectives:** to evaluate the Role OF Capnography in Weaning in Mechanically Ventilated COPD Patients. **Subjects and methods:** Comparative prospective single group observational study was conducted in the Critical Care Department – Benha University Hospitals. The study was conducted upon fifty mechanically ventilated patients (36 males &14 females) **Results:** there was a statistically significant difference between the studied population regarding correlation coefficient between PaCO2 and PETCO2 before and after weaning, validity of PaCO2 and PetCO2 in prediction of successful weaning and comparison between patients with successful and failed weaning regarding outcome except in SOFA and APACHE score. There was no statistically significant difference between the studied population regarding comparison between patients with successful and failed weaning regarding vital signs and comparison between patients with successful and failed weaning regarding blood gases except in PaCO2 and HCO2. **Conclusion:** the present study found that PacO2 and PetCO2 are correlated to each other before, during and after SBT. Most of the studies that was found reported that PetCO2 is highly correlated with PaCO2 and that PetCO2 may be a rapid and reliable predictor as arterial PaCO2 in respiratory distress.

Keywords: Capnography, Mechanically ventilated COPD, Weaning.

Introduction

Patients with chronic obstructive pulmonary disease (COPD) suffer from chronic inflammation of small airways and lung parenchyma, resulting in obstructive bronchiolitis, parenchymal destruction, and emphysema. Increased airway resistance and decreased elastic recoil led to limited airflow and an impaired ability of the airways to remain open at the end of expiration. In turn, the collapse of airways at the end of expiration results in incomplete expiration, higher residual end-expiratory volume, hyperinflation, and auto– positive end-expiratory pressure (auto-PEEP). Progression of chronic inflammation and parenchymal destruction result in impaired gas exchange with hypoxemia and hypercapnia. In case of the need for ventilatory support for acute exacerbations, the use of noninvasive mechanical ventilation reduces mortality in patients with COPD [1, 2].

ETCO2 estimations are influenced in general by PaCO2 levels, volume of dead space, and pulmonary vasculature. ETCO2 mainly relies on alveolar CO2 (PACO2). Nonhomogeneous alveoli CO2 emptying patterns as occurred in patients with ventilation/perfusion mismatch will lead to mismatched PACO2 and underestimation of PaCO2 levels [3].

A high ventilation/ perfusion ratio and increased dead space volume lead to low ETCO2 levels in comparison with PaCO2, whereas a low ventilation / perfusion ratio has diminished effect on producing smaller ETCO2 levels in comparison with PaCO2. Usually, there is a difference between PaCO2 and ETCO2 of approximately 2–5 mmHg in normal intubated patients, and this difference increases with age, pulmonary diseases, impairment of cardiac function, and others conditions that are commonly found in patients admitted to emergency department for respiratory distress [4].

Monitoring capnography can help with management and disposition in those with COPD or asthma. During exacerbations, EtCO2 levels may initially drop as the patient hyperventilates to compensate [5].

It is not until ventilation becomes less effective that EtCO2 levels begin to rise. This may occur before hypoxia sets in and can prompt the clinician to escalate ventilation strategies. In addition, the normalization of the “sharkfin” obstructive pattern towards the more typical box-form wave may indicate effective treatment, though more data is needed before it can be recommended [6].

Patients and Methods

This study was conducted on 50 mechanically ventilated COPD patients admitted at the Intensive Care Unit of the Benha University Hospitals. patients with COPD with acute exacerbation that complicated by acute respiratory failure in top of chronic state, the whole subjects were mechanically ventilated During the weaning trial, the role of capnography device (Figure: 1) evaluated considering the ability of $PetCO_2$ parameters in predicting hypercapnia and subsequently weaning outcome. Comparative prospective single group observational study was conducted in the Critical Care department – Benha University Hospitals. The study was conducted upon fifty mechanically ventilated patients (36 males &14 females) Table (1) presented to Critical care department, Benha university hospitals during a period of 14 months starting from Mars 2022 to April 2023. The study was approved by Institutional Review Board of Benha University {MD.7.9.2021}

Inclusion Criteria: All COPD patients admitted to our ICU on mechanical ventilation and ready for weaning with the following criteria: All are afebrile for at least 24hours before the study, During a brief trial of spontaneous ventilation, each could match the minute volume that delivered by the ventilator, The pao2 at least 75mmHg on fio2 50% or less and arterial PH 7.35and 7.46 and Patients with convential trials tests that predict weaning success are marginal (maximum inspiratory force ,spontaneous vital capacity, minute ventilation to maintain isocapnia). [7]

Exclusion Criteria: Dyspnea clearly related to a different aetiology (e.g., trauma, anxiety, heart failure, etc)**,** evidence of diaphragmatic or neurologic injury and Sedations or narcotics at least 8 hours before the study.

All patients were subjected to the following: History (present, past, family), Examination (general and local chest), Laboratory examination (CBC- urea, creatinine, ABG, SGPT), continuous capnography waveform registration, CUS (Figure 1), Chest X ray and C.T chest.

The patients were evaluated for any possible lung pathology according to the modified lung ultrasound protocol (figure 2).

Figure (1): Philips Ultrasound machine and convex probe.

Figure (2): NIHON KOHDEN monitor and mainstream capnography.

Methods of discontinuing Mechanical Ventilation

SIMV with PSV, Continuous Positive Airway Pressure (CPAP), BIPAP, Pressure Support Ventilation (PSV) and Non-invasive Positive Pressure Ventilation (NIPPV).

Statistical analysis of the data

Data was fed to the computer and analyzed using IBM SPSS software package version 25.0 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp). Qualitative data were described using numbers and percentage. The Shapiro-Wilk test was used to verify the normality of distribution. Quantitative data were described using range (minimum and maximum), mean, and standard deviation, median and interquartile range (IQR). The significance of the obtained results was judged at the 5% level.

The used tests were Chi-square test, Mann Whitney test, The Kruskal-Wallis's test, Wilcoxon Rank test and 5- Logistic Regression.

Results

[Table 1] The age of studied patients ranged from 42 to 79 years with mean age was 57.90± 9.14 years. There were 36 (72%) males and 14 (28%) females with male: female ratio was 2.57:1. 27 (54%) patients were smokers, 11 (22%) patients were ex-smokers, and 12 (24%) patients were non-smokers.

[Table 2] There was a highly statistically significant positive correlation between PaCo2 and PETCO2 before weaning and after weaning.

Table (1): Demographic data on the studied patients.

Variables		Studied patients (No=50) No.	%
Gender	**Male**	36	72.0%
	Female	14	28.0%
Age (years)	**Mean± SD**	57.90± 9.14	
	Range	42– 79 years	
Special habits (Smoking)	**Smoker**	27	54.0%
	Ex-smoker	11	22.0%
	Nonsmoker	12	24.0%

Table (2): Correlation coefficient between PaCO2 and PETCO2 before and after weaning.

		PETCO2 R	p- value
PaCO2	**Before weaning**	0.974	**<0.001**
	After weaning	0.978	**<0.001**

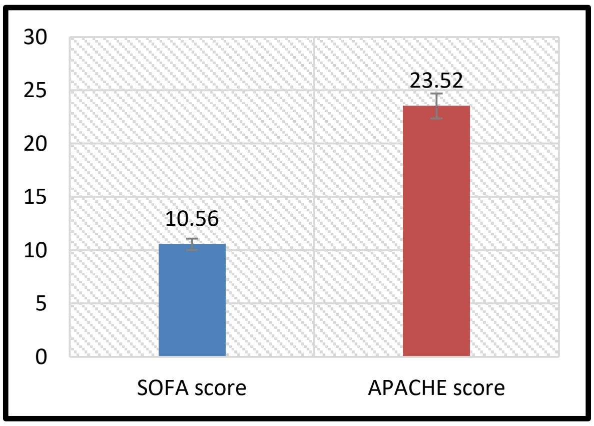

Figure (3): Mean SOFA & APACHE scores among studied patients.

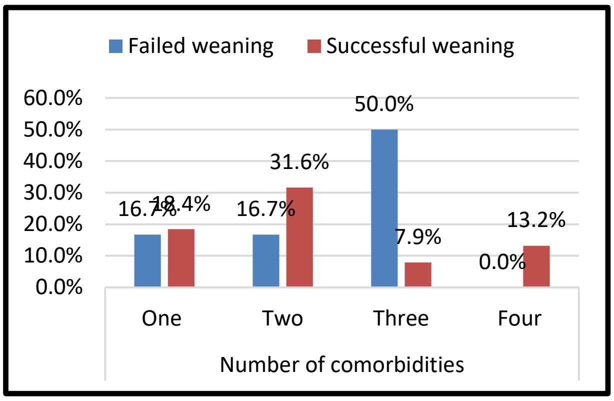

Figure (4): Comparison between patients with successful and failed weaning regarding number of comorbidities.

[Table 3] There was no significant association between failure of weaning and vital data include blood pressure, heart rate, respiratory rate and GCS (p>0.05).

[Table 4] Patients with failed weaning had significant higher PCO2 and HCO3 level in comparison with successful group (p<0.001& p=0.002 respectively).

[Table 5] Patients with failed weaning needed significantly prolonged mechanical ventilation time than those with successful weaning trial, (P<0.001). In addition, the group of patients suffered significantly from prolonged length of ICU Stay in hospital than the other successful one, (p=0.008). PetCO2 and resistance was significantly higher in patients with failed weaning (p<0.001 &p=0.001 respectively). [Table 6] Receiver operating characteristic (ROC) analysis was performed to determine diagnostic value of PCO2 and PetCO2 in prediction of successful weaning. PCO2 can determine successful weaning at cutoff of 45 with sensitivity, specificity, PPV and NPV was 65.8%, 100%, 100% and 74.5% respectively (p< 0.001) with AUC was 88.8%. while PetCO2 can determine successful weaning at cutoff of 54 with sensitivity, specificity, PPV and NPV was 92.1%, 66.7%, 73.5% and 89.4% respectively (p< 0.001) with AUC was 86.6%. Using both PCO2 and PetCO2 increased the sensitivity and specificity to 71.1% & 100% respectively with AUC was 88.8%.

Table (3): Comparison between patients with successful and failed weaning regarding vital signs.

Variables		Outcome of weaning				p-value
		Failed (N=12)		Success (N=38)		
		No.	%	No.	%	
Blood pressure	Normal	4	33.3%	24	63.2%	0.188*
	High	2	16.7%	3	7.9%	
	Low	6	50.0%	11	28.9%	
Heart rate (beats/min.)	Mean± SD	106.08± 18.69		105.35± 24.22		0.691$
	Range	80.0- 140.0		70.0- 180.0		
Respiratory rate (/min.)	Mean± SD	25.5± 3.4		27.71± 4.52		0.126#
	Range	22.0- 34.0		20.0- 36.0		
GCS	Mean± SD	10.50± 2.11		10.92± 1.7		0.271$
	Range	7– 14		6– 14		

P value< 0.05 is significant, SD: Standard deviation, * Chi- Square test, # Student T Test, $: Mann Whitney U test

Table (4): Comparison between patients with successful and failed weaning regarding blood gases and ventilator settings.

	Outcome of weaning				P-value
	Failed (N=12)		Success (N=38)		
	Mean	±SD	Mean	±SD	
Blood gases					
PH arterial	7.39	±0.05	7.39	±0.05	0.792$
Po2	81.58	±6.54	80.42	±9.10	0.794$
PaCO2	53.08	±5.50	43.97	±5.33	**<0.001#**
HCO3	36.42	±5.21	31.79	±4.07	**0.002$**
Pulmonary function					
Pao2/Fio2	87.08	±11.96	85.82	±9.80	0.316$
RSBI	472.50	±37.63	482.63	±42.42	0.688$
TV	6.42	±1.16	5.95	±0.87	0.620$
PEEP	24.50	±8.49	23.39	±6.62	0.186$
P PLAT	22.83	±2.98	23.71	±3.47	0.715$
Ppeak	87.08	±11.96	85.82	±9.80	0.556$

P value< 0.05 is significant, SD: Standard deviation, # Student T Test, $: Mann Whitney U test

Table (5): Comparison between patients with successful and failed weaning regarding outcome.

	Outcome of weaning				P-value
	Failed (N=12)		Success (N=38)		
	Mean	±SD	Mean	±SD	
SOFA score	10.33	±2.77	10.63	±3.15	0.721$
APACHE score	27.42	±5.58	22.29	±6.15	0.042$
Duration of MV (days)	7.75	±2.18	4.61	±2.09	**<0.001$**
Length of ICU Stay (days)	10.33	±2.77	7.61	±2.93	**0.008#**
PetCO2	55.58	±6.30	45.63	±6.03	**<0.001#**
Compliance	30.75	±14.67	31.66	±12.36	0.617#
Resistance	11.50	±2.84	9.05	±1.64	**0.001$**

P value< 0.05 is significant, SD: Standard deviation, # Student T Test, $: Mann Whitney U test

Table (6): Validity of PaCO2 and PetCO2 in prediction of successful weaning.

Parameters	Cutoff value	AUC	Sensitivity	Specificity	PPV	NPV	P value
PaCO2	45	0.888	65.8%	100%	100%	74.5%	**<0.001**
PetCO2	54	0.866	92.1%	66.7%	73.5%	89.4%	**<0.001**
PetCO2+ PaCO2	-	0.889	71.1%	100%	100%	77.8%	**<0.001**

PPV= Positive Predictive Value, NPV= Negative Predictive Value, AUC= Area Under Curve

Discussion

In the current study (Table 1), the mean age of the studied patients was 57.90± 9.14 years, distribution of 36(72%) males and14(28%) females with male: female ratio was 2.57:1. 27(54%) patients were smokers, 11 (22%) patients were ex-smokers, and 12 (24%) patients were non-smokers.

The majority of them were males and smokers; 78% and 74% respectively, Similarly, researchers reported that the mean age was 61.13 ± 8.18 and about 60% of the sample were males. This is probably because smoking is much more prevalent between males [(8)].

It was reported that Chronic Obstructive Pulmonary disease (COPD) is a major and growing cause of morbidity and mortality in countries at all levels of economic development with smoking being recognized as its most important causative factor. [(9)].

In the current study, it was found that about 32% of cases, had associated comorbidity; (74%) of the cases had one comorbidity, DM, IHD, HTN, CKD or AF. Another study reported that Tobacco smoking is a risk factor for many of these comorbidities as well as for COPD, making it difficult to draw conclusions about the relationship between COPD and these comorbidities. However, recent large epidemiologic studies have confirmed the independent detrimental effects of these comorbidities on patients with COPD. On the other hand, many of these comorbidities are now considered to be part of the commonly prevalent non-pulmonary sequelae of COPD that are relevant not only to the understanding of the real burden of COPD but also to the development of effective management strategies (Table1) [(10)].

It was also found that there was slight elevation in urea levels as well as in liver enzymes levels (SGPT& SGOT). One explanation of elevated liver enzymes in COPD patients is hypoxic hepatitis which is a liver injury with typical clinical, biochemical, and histological features.

This was described by who studied the hypoxic hepatitis and its relation to chronic respiratory failure in COPD patients reported episodes of hypoxic (ischemic) hepatitis occurring during acute exacerbation of respiratory failure (CRF) which occur in obstructive lung disease eventually [11].

In the current study it was found that PaCO2 can determine successful weaning at cutoff of 45 with sensitivity, specificity, PPV and NPV was 65.8%, 100%, 100% and 74.5% respectively ($p < 0.001$) with AUC 88.8%. While PetCO2 can determine successful weaning at cutoff of 54 with sensitivity, specificity, PPV and NPV was 92.1%, 66.7%, 73.5% and 89.4% respectively ($p < 0.001$) with AUC 86.6%. Using both PCO2 and PetCO2 increased the sensitivity and specificity to 71.1% & 100% respectively with AUC was 88.8 % (Table 6).

Similarly, reported that Capnography provided good assessment of hypercapnic episodes during weaning although the high number of false positives may result in arterial blood sampling in patients who do not present with ventilation failure [12].

In the current study, regarding the vital signs of patients during the weaning trial, it shows stabilization of all vital parameters which is probably due to the fairly good clinical condition and good treatment measures of patients in the study group. This also may explain the high success rate of SBT and subsequently successful extubation which was 76%. It was also found that at the start of weaning trial, the pulse of patients in failed group was significantly higher in comparison with the successful group of patients. This may be due to hypoxia in failed group which lead to higher heart rate to compensate the lack of oxygen for cells (Table 3) [13].

Similarly, while studying the prognostic value of the dead-space fraction and other physiological parameters in the weaning process of mechanical ventilation in patients with obstructive air flow, found that patients who had failed SBT had much higher mechanical ventilation duration [14].

It was performed a study in which the ability of [Pa-ET) CO2] as a predictor of progressive ventilator support reduction, predictor of weaning from mechanical ventilation and for extubation success was evaluated. It was reported that P(a-ET) CO2 may be used as a predictor of weaning during progressive weaning from mechanical ventilation, spontaneous breathing trial and to predict success of extubation.(Table 2) [15].

In the current study it was found that the PETCO2 ranged from 22 to 65 with mean of 41.86± 4.52 while after weaning, it ranged from 37 to 80 with mean of 48.02± 3.41. There was significant increase of PETCO2 before weaning when compared to after weaning ($p<0.001$). Before weaning, the mean value of pH was 7.39± 0.05, the mean Po2, PCO2, and HCO3 was 80.70± 8.51, 46.16± 6.61 and 32.90 ±4.75 respectively. After weaning, the mean value of pH was 7.42±0.06, the mean PO2, PCO2, and HCO3 was 88.64±7.86, 53.27±5.64 and 37.08 ±3.86 respectively. There were significant changes in values of pH, PO2, PCO2, and HCO3 Before weaning when compared to after weaning (Table 4).

This may be attributed to the insufficient spontaneous respiration in failed patients' group. These patients were unable to supply their bodies with sufficient oxygen which leads to lower Pao_2 and O_2 saturation and elevated PCO_2 and $PetCO_2$.

Similarly, a study by reported results similar to the ones found in the current study, that there is highly statistically significant difference between failed and successful weaning groups regarding respiratory rate, PaO_2, PCO_2, PaO_2/FiO_2 rate, V_T and RSBI. PCo2 levels were higher in the failed group in comparison to the successful group. While Pao2 levels were higher in the successful group (Table 4) [16]

Similarly, conducted a study to determine the reliability of noninvasive end-tidal CO_2

($PetCO_2$) monitoring as a reflection of arterial CO_2 tension ($PaCO_2$) during weaning from mechanical ventilation (MV), and found that Significant Person correlation coefficients were demonstrated between Pa_{CO2} and Pet_{CO2} during both MV and spontaneous breathing in patients recovering from acute respiratory failure (Table 5). However, Pet_{CO2} is less sensitive to changes in Pa_{CO2} for patients with parenchymal lung disease, particularly patients with emphysema. Interpretation of capnographic data requires a full understanding of its limitations [(17)].

Conclusion

The present study found that PaO_2 and $PetCO_2$ are correlated to each other before, during and after SBT. Most of the studies that was found reported that $PetCO_2$ is highly correlated with Paco2 and that $PetCO_2$ may be a rapid and reliable predictor as arterial $PaCO_2$ in respiratory distress.

Conflict of Interest

None of the contributors declared any conflict of interest.

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