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Faculty of Graduate Studies

**The Impact of Educational Sessions on Ventilator
Waveforms Knowledge among Palestinian ICU
Nurses: Quasi Experimental Study**

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**This thesis was submitted in partial fulfillment of the requirements for
the Master`s degree in Nursing**

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**The Impact of Educational Sessions on Ventilator Waveforms
Knowledge among Palestinian ICU Nurses: Quasi Experimental Study**

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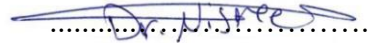
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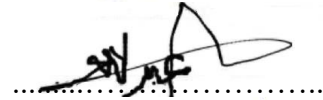
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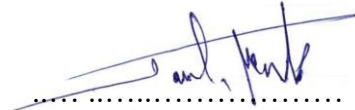
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Declaration

I certify that this thesis submitted for the degree of master, is the result of my own research, except where otherwise acknowledged, and that this study has not been submitted for another degree, university, or institution.

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Dedication

My research is dedicated to the Almighty Allah to save my life; give me passion, ambition, and capabilities to complete this work.

To my lovely family and colleagues who give me support, love, and inspiration, who always motivate me to succeed in my life.

To my supervisors for their assistance.

To my friends for their encouragement.

Acknowledgement

First, I give all the glory to God, the source of my strength; I would like to express my gratitude to my awesome supervisor Dr. Imad Abu Khader for his precious support and engagement through the learning process of this master thesis and endless help in the statistical analysis.

Also, I would like to thank all the people who contribute to develop this work.

Abstract

Introduction: The waveforms of ventilators include a knowledge that is critical for safe and successful mechanical ventilation. In critical care circumstances, its interpretation by competent healthcare practitioners enables accurate modifications, timely treatments, and improved patient outcomes. This study was aimed to investigate the knowledge level among Palestinian ICU nurses about MV waveforms and the impact of education sessions on it.

Methodology: The researcher utilized a one group pretest and posttest quasi-experimental quantitative design on a convenience sample of 72 ICU nurses in West Bank – Palestine, which received an educational session related to MV waveforms by a specialist, and received a pretest and posttest questionnaire that was developed based on previous literature. The data were analyzed using SPSS software, where summary measures (i.e., frequencies, mean, standard deviation, ..., etc.) were used to describe the data and inferential tests (i.e., t-test, Chi-square test, one-way analysis of variance, ..., et). were conducted to investigate the relationships and differences between study variables. Data was collected in an anonymous and confidential manner.

Results: Main results showed that 50% of the nurses were male, with a mean age of 28.44 ± 4.75 years old, 6.34 ± 4.33 and 4.66 ± 3.63 years of experiences in nursing and ICU settings, respectively, with a mean pretest score of knowledge equals to $43.704\% \pm 16.67\%$, that was significantly related to older nurses' age and higher ICU experience (p -value = 0.019 and 0.004, respectively), which significantly increased to a mean posttest score of $67.315\% \pm 16.53\%$, that was also significantly related to older nurses' age and

higher ICU experience (p-value = 0.039 and 0.004 , respectively) , in which the score increase was not significantly related to any of the demographic or professional factors.

Conclusion: There is a positive impact of educational sessions on the knowledge of MV waveforms among Palestinian nurses. There is a need to conduct further studies to evaluate the impact over multiple time points post-educational sessions, as well as the comparison between several specialties. Continuous education efforts should also proceed inside health institutions in Palestine.

Keywords: Mechanical Ventilator, Waveforms, Graphics, Educational Sessions, Asynchrony.

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List of Abbreviations

Abbreviation	Meaning
MV	Mechanical Ventilation/Ventilator
ETT	Endotracheal Tube
ICU	Intensive Care Unit
CO₂	Carbon Dioxide
VC	Volume-controlled
PC	Pressure-controlled
AC	Assisted- control
SIMV	Synchronized Intermittent Mandatory Ventilation
PS	Pressure Support
PRCV	Pressure-regulated Volume Controlled
V_t	Tidal Volume
AUC	Area Under the Curve
PEEP	Positive End-expiratory Pressure
HCP	Healthcare Provider
VAP	Ventilator-Associated Pneumonia
PVA	Patient-ventilator Asynchrony
RCT	Randomized Control Trial
LOS	Length of Stay
CCU	Cardiac Care Unit
PMC	Palestine Medical Complex
SPSS	Statistical Package for Social Sciences

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Chapter One: Introduction

Background

The first apparatus of a mechanical ventilator that was presented in the recent medicine was discussed and explained by Drinker and Shaw (1929), in which the authors described it as positioning the patient in an “entirely enclosed cylindrical sheet-metal tank sealed at one end”, while the other end includes a rubber collar attached to a flat lid that surrounds the patient’s neck, and therefore the patient’s body is affected by the pressure changes inside the cylindrical tank, while the head is kept under the effect of atmospheric pressure, where decreased pressure inside the tank allows the outside air to rush into the lung as the chest expands, and the opposite happens when the pressure is increased, so the chest is compressed and the air is forced to leave the chest. The term that was used for this apparatus is “iron lung”. The main event in the previous century that provoked the development of mechanical ventilation (MV) is the paralytic poliomyelitis, in which Lassen (1953) presented a recommendation for the use of positive pressure ventilation to treat the patients by squeezing a rubber bag that is attached to an endotracheal tube (ETT), which was manually performed by 1500 medical students, and virtually decreased the mortality rate among the patients overnight from 87% to 40%, and was provided in what can be named the first intensive care unit (ICU).

After that, the need for mechanically- assisted positive ventilation increased due to the difficulties of manual ventilation, which was developed for the first time by a Danish physician and a Swedish anesthesiologist, with the mere basic principle of the need to eliminate the carbon dioxide (CO₂) from the body, and to quantitatively provide air entry in an equal and uniform manner to both lungs (Engstrom, 1954). Nowadays, mechanical ventilators (MVs) are more compact, computerized, and electronically more

than pneumatic-based and includes a variety of mechanical ventilation modes and advanced parameters monitoring abilities.

MVs are basically assist devices that utilize several parameters, like pressure, volume, flow, and time, whether used as independent or dependent variables, and are set by clinicians to determine ventilation modes, in order to provide the patient with tidal breath under positive pressure. Modes are mainly classified to two types: volume-controlled (VC), where the tidal volume is set and the pressure is resulted and not set, and pressure-controlled (PC), which is the exact inverse, where the pressure is controlled and the resulted volume is not, taking in consideration that the ventilation modes are described by three fundamental terms: trigger (the stimulus that initiates the mechanical breath, which can be volume- or pressure-triggered), target (the strategy that the MV uses to deliver the breath), and the cycle (the termination basis of the breath). According to the rest of parameters, there are two common modes under the VC type, which are the assist control (AC) and synchronized intermittent mandatory ventilation (SIMV), while there are two more common modes rather than AC and SIMV that set under the PC type, which are the pressure support (PS) and pressure-regulated volume controlled (PRVC), and are selected upon the patient's chief complain and diagnosis, as well as sedation and awareness level (Walter, Corbridge, & Singer, 2018).

Majority of the modern MVs utilize the same basic physiological principle, in which breath-to-breath detailed pulmonary function testing physiologic measurements are obtained, and the respiratory system motion is described by a single equation regarding the forces that are playing during the ventilation process at any time point. This equation was detailed by Pham, Brochard, and Slutsky (2017) as the following:

$P_{aw} = P_0 + (R \times \text{flow}) + (V_t \times E_{RS})$, where P_{aw} = airway pressure (at the airway opening),

P_0 = initial alveolar pressure, R = resistance to flow, V_t = tidal volume, and E_{RS} = elastance of the respiratory system, and is represented in Figure 1. In general, the alveolar pressure at the beginning of the respiration can be equal to or higher than (positive) atmospheric pressure, while the elastic characteristics of the respiratory system are the opposite of its compliance, and the resistance represents the difference in the pressure that is needed to generate the flow.

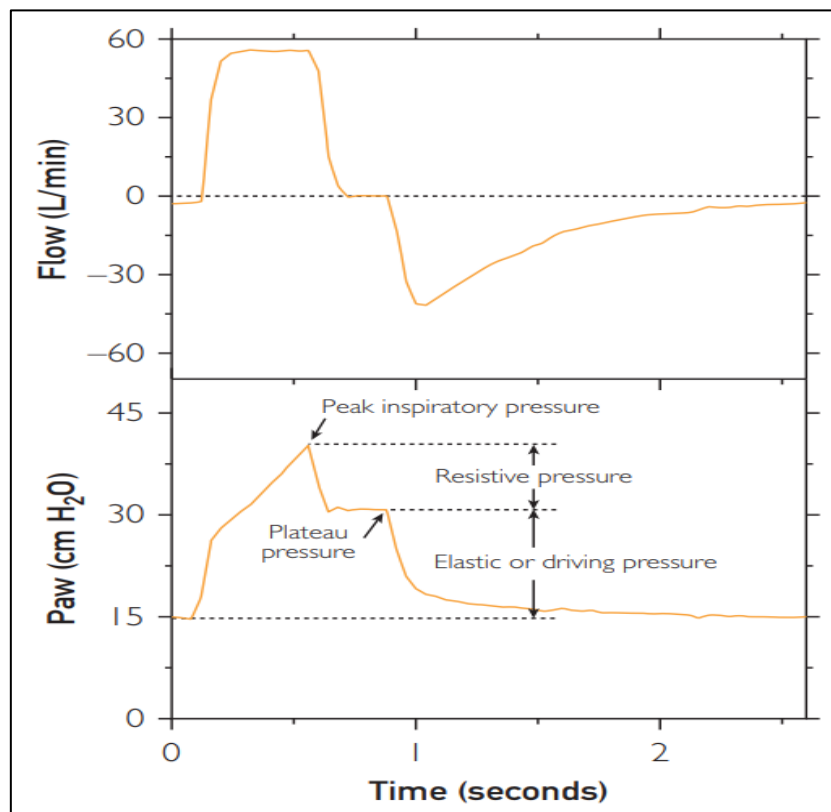


Figure 1: Explanation of ventilator waves, P_{aw} = airway pressure
(Pham et al., 2017)

Some of the terms are viewed and can be interpreted when analyzing MV waveform. For example, area under the curve (AUC) is the calculated area according to the mathematical equation of the shape, and it represents the mean airway pressure (P_{awmean}), which directly correlates with oxygenation (Sottile, Albers, Smith, & Moss,

2020). Another term is auto-PEEP, which is the alveolar auto generated positive end-expiratory pressure (PEEP) that results from dynamic hyperinflation, that is defined as the end-expiratory lung volume increase that is sustained by expiration incompleteness (Natalini et al., 2016).

According to the controlled parameters, as well as the intended monitored aspects of the respiratory system, waveforms are represented in different shapes and figures. There are several waveform shapes and traces that help in monitoring a patient's respiratory system interaction with the settings of the MV, and each of them represents a specific relationship and is used for some of the most common indications, which are explained by Maung and Kaplan (2013). For example, the pressure-time trace (Figure 2) displays the airway pressure as a function of time, noticing that the square-shaped waveform results in shorter inspiratory time (T_i), higher peak airway pressure and smaller area under the curve (AUC), and the opposite is for the decelerating waveform, and this trace is suitable to be interrogated by clinicians to monitor auto-PEEP, because adjusting mechanical ventilator aspects may affect T_i and therefore affecting time of expiration (T_e), which may limit the expiratory flow and undesirably create auto-PEEP. Another form is the flow-time trace, which monitors the amplitude and duration of the flow, and has a negative flow representing the exhalation (Figure 3). The normal situation includes the return of the flow to the baseline before initiating the next breath, and therefore, failure to return to the baseline reflects air trapping, creating auto-PEEP. The monitoring of flow-time trace helps in selecting sedation and analgesia plan when there are extra spontaneous breaths that shortens T_e and creating auto-PEEP because of the air trapping.

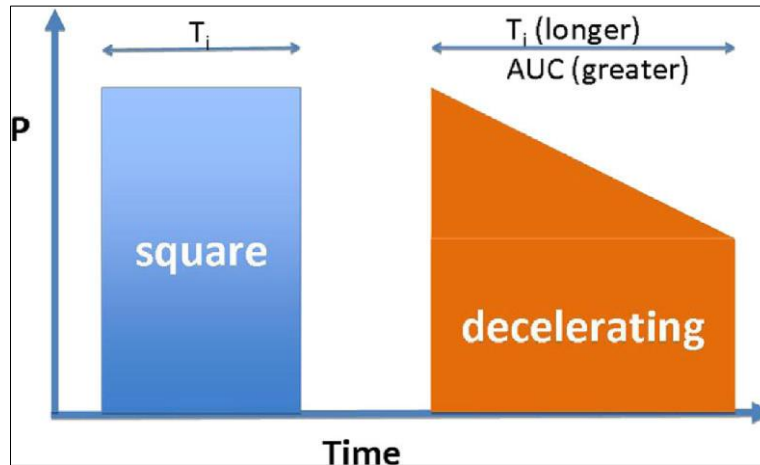


Figure 2: Square and decelerating pressure-time trace
(Maung & Kaplan, 2013)

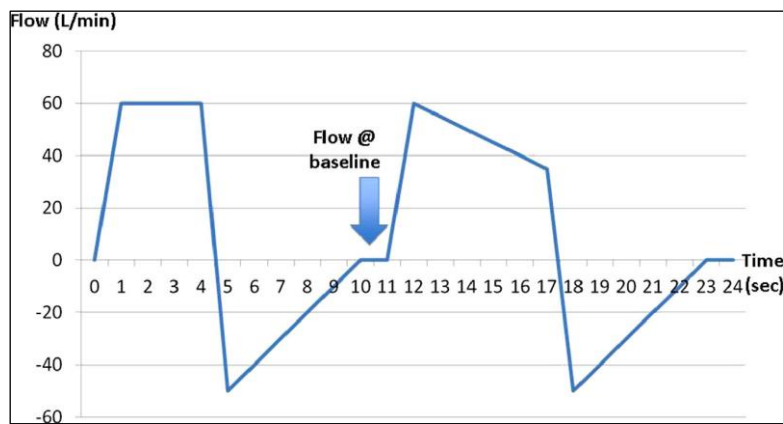


Figure 3: Square to decelerating flow-time trace
(Maung & Kaplan, 2013)

Rather than traces, loops are also used as a second type of waveforms and reflect further specific aspects of the respiratory dynamics. For example, pressure-volume dynamic loop, which is displayed in the most modern MVs, is a useful measure to how the gas is received and delivered to the patient's lung. Normally, as shown in Figure 4, it starts at the set PEEP, and smoothly rises to the desired volume (shown in the resultant peak pressure), with resistive work represented in the right side and the elastic work is represented in the left side of the loop. One of the cases that is monitored using this dynamic loop is the insufficient PEEP inside the patient, which is demonstrated by adherence of the line to the baseline before rising, while Figure 5 shows alveolar

overdistension, illustrated in the bird's beak. Another loop is the dynamic flow-volume loop, which is suitable for determining changes in airway resistance affected by specific elements, like secretions and reactive airway disease. As shown in Figure 6, the start of the breath is in the far left, and the inhalation is represented in the downward deflection, while the exhalation is represented in the upward deflection. The shape represents the normal process in which that 80% of the expiratory flow happens in the first 1 second, and many respiratory system abnormalities appear using this loop, including airway resistance (Figure 7), in which the inhalation curve becomes closer to the x-axis, and the clinician may use it to evaluate the effect of the used bronchodilators. Moreover, air leakage appears as a failure of the exhalation trace to return to the baseline (Figure 8).

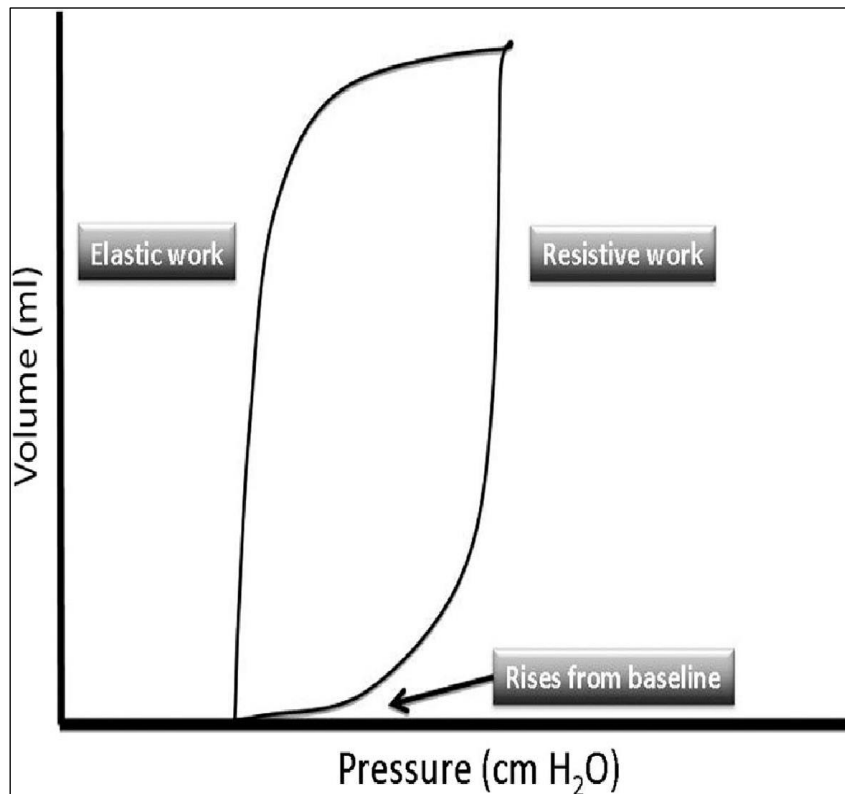


Figure 4: Dynamic pressure-volume loop
(Maung & Kaplan, 2013)

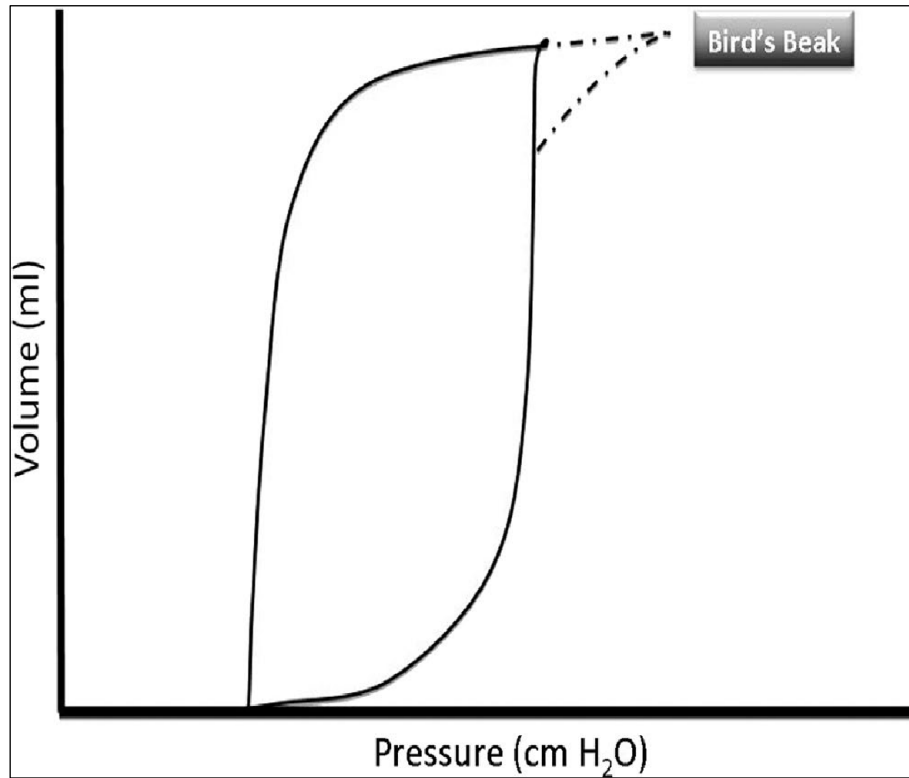


Figure 5: Alveolar overdistension shown in the dynamic pressure-volume loop
(Maung & Kaplan, 2013)

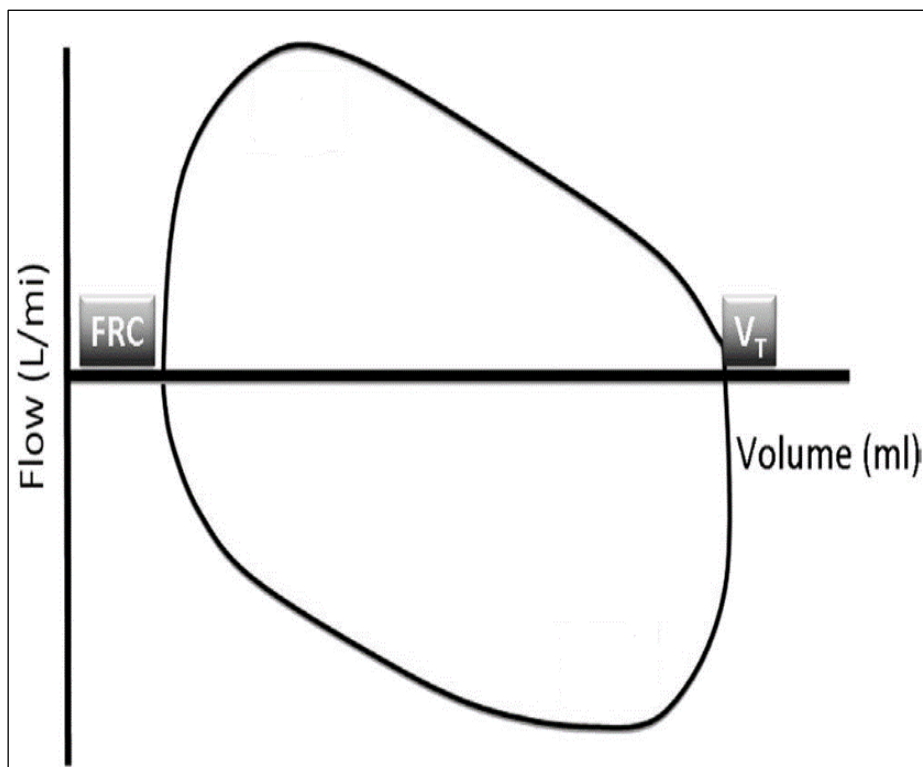


Figure 6: Flow-volume dynamic loop
(Maung & Kaplan, 2013)

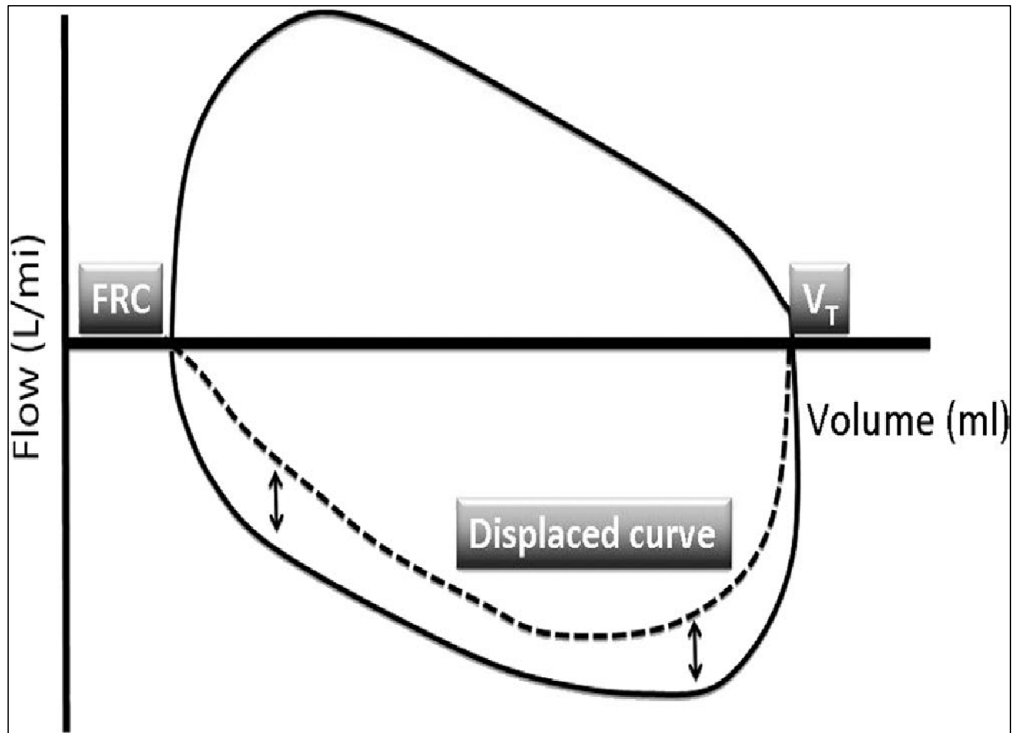


Figure 7: Airway resistance as appeared in flow-volume dynamic loop
(Maung & Kaplan, 2013)

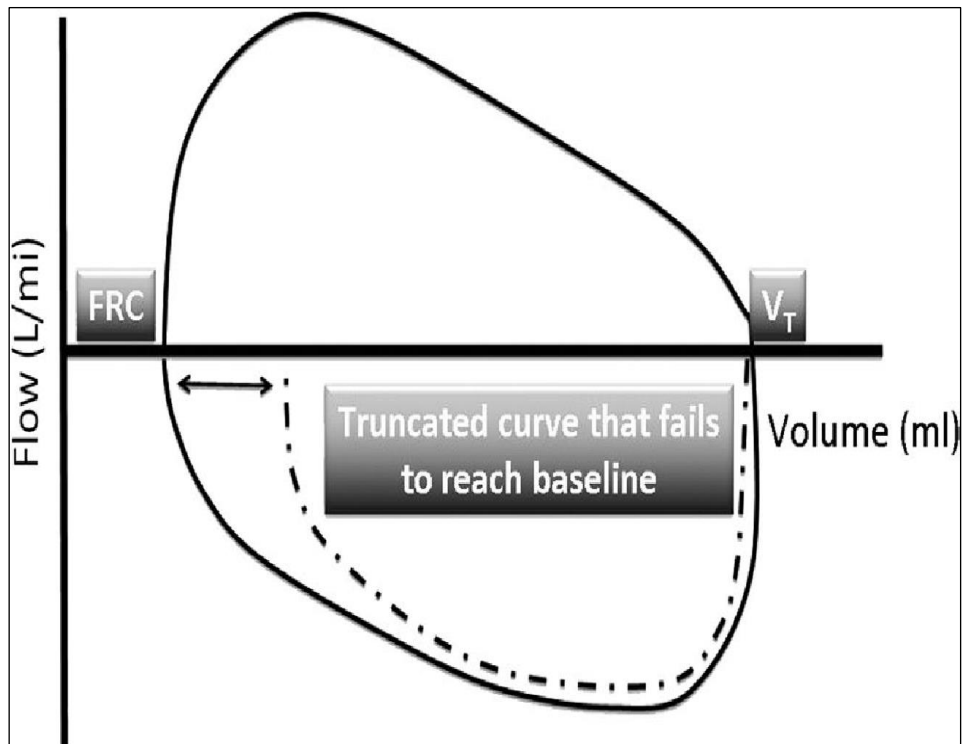


Figure 8: Air leak detection using flow-volume dynamic loop
(Maung & Kaplan, 2013)

MV waveform also help in determining the patient-ventilator interaction, which was classified according to the review of Mireles-Cabodevila, Siuba, and Chatburn (2021) to four major interactions. The normal and desired interaction is the “synchrony”, in which there is a near-zero phase difference between both patient’s signal (i.e., triggering) and ventilator’s response, while there are two abnormal interactions that may be difficult to be distinguished by the clinicians. The first is called “asynchrony”, which is from a-, indicating the absence of, and is defined as the absence failure of patient’s triggering to the ventilator’s response, or vice versa, while the second term is “dyssynchrony”, which is from dys-, indicating the difficulty, bad or abnormal, in which there is a phase timing difference between the patient’s signal and ventilator’s response. The final interaction is called the “work shifting”, which includes the activation of patient’s muscular action and ventilator’s response together, and therefore some portion of the overall work is done by the ventilator while the other is done by the patient.

There are also several classifications of the asynchronies according to different aspects, and one of the most commonly used aspects is regarding the ventilation phase. During inspiratory period, asynchronies may be related to triggering delay, inspiratory flow mismatching, reverse triggering or short/prolonged cycling, while during the inspiration-to-expiration transition period, asynchronies may be manifested by double triggering related to short cycling or reverse triggering, and the contraction of expiratory muscles caused by prolonged cycling, with asynchronies happening during the expiratory period related to ineffective inspiratory effort, expiratory muscle contraction or auto-triggering. Moreover, the management of each cause or type of asynchrony is established based on the desired outcome and patient’s individual condition, as well as the specific

underlying mechanical or patient-related cause of the asynchrony (Subirà, de Haro, Magrans, Fernández, & Blanch, 2018).

There are two main approaches in the management of asynchronies among mechanically ventilated patients, which are the ventilator settings' adjustment and analgesia or sedation. Therefore, the clinician's ability to interpret the MV waveforms in a proper way is crucial in the management of critically- ill patients (Esperanza et al., 2020).

Accurate waveform interpretation enables nurses to detect abnormal patterns or aberrations in waveforms, such as rapid changes in airway pressures or flow patterns, in real time. This early detection is crucial for quickly diagnosing and managing difficulties such as endotracheal tube dislodgement, pneumothorax, or mucus clogging, ensuring that corrective actions are implemented as soon as possible to avoid adverse consequences (Smith et al., 2020).

Understanding MV waveforms allows nurses to determine whether the patient's current ventilator settings are appropriate for his or her condition. Nurses can make informed decisions about adjusting parameters like tidal volume, PEEP (positive end-expiratory pressure), or inspiratory pressures to optimize oxygenation and ventilation by attentively watching the waveforms. This guarantees that the ventilator is adjusted to the patient's unique demands, resulting in improved respiratory support and a lower risk of ventilator-associated lung injury (Beckmann et al., 2019).

Problem Statement

The main deficit that is manifested in the clinical settings is the dependence on the numerical evaluation of the MV settings and outcomes to evaluate the intubated patients' respiratory system condition, while the integration of MV waveforms is essential and useful, and should be embraced (Maung & Kaplan, 2013).

Understanding MV waveforms allows nurses to determine whether the patient's current ventilator settings are appropriate for his or her condition. Nurses can make informed decisions about adjusting parameters like tidal volume, PEEP (positive end-expiratory pressure), or inspiratory pressures to optimize oxygenation and ventilation by attentively watching the waveforms. This ensures that the ventilator is adjusted to the patient's unique demands, providing improved respiratory support, and lowering the risk of ventilator-associated lung injury. Despite the crucial necessity of these abilities, there is rising worry about the heterogeneity in Palestinian ICU nurses' knowledge and competency in interpreting MV waveforms (Palestinian Ministry of Health, 2021). This knowledge gap not only endangers patient safety, but it also impedes the delivery of high-quality critical care. To address this issue, it is critical to evaluate the impact of instructional sessions geared to improve nurses' knowledge and competency in interpreting MV waveforms in the setting of the Palestinian ICU.

There is also a lack in the studies of MV-related topics in the Palestinian and local literature that include level of knowledge about MV waveforms and their interpretations, as well as the effectiveness of educational sessions and training in changing the level of knowledge and practice toward such an important topic among health care providers (HCPs) in the critical care settings.

Significance of the Study

The measurement of respiratory system mechanics helps in facilitating the differential diagnosis development, which in turn guides the mechanically ventilated patients' initial management, especially in times when they experience sudden airway pressure changes, and the main guidance for such changes is MV waves (Walter et al., 2018).

Moreover, MV-derived waveform understanding requires a pulmonary physiology basic knowledge, and patients' responses to MV prescription (i.e., modes and parameters) are reflected by the presented waveforms and traces, which the clinicians need to be ready to interpret the commonly used types of them. Also, clinicians who care for mechanically ventilated patients need to implement, track, and analyze the graphical changes to set the right and most suitable management plan (Maung & Kaplan, 2013).

Inadequate knowledge of MV waveforms might result in delayed detection of adverse events or poor ventilator settings, possibly risking patient safety. Investigating the influence of teaching sessions on waveform interpretation can help to improve ICU safety (Vincent, 2017).

Objectives of the Study

The study will try to achieve the following objectives:

- 1- Identify the level of knowledge about the most common and important mechanical ventilators waveforms identification and interpretation among nurses in the targeted settings.
- 2- Identify the most common factors that help or hinder the increasing in nurses' level of knowledge about mechanical ventilator waveforms.

- 3- Investigate the effect and role of educational sessions on the level of knowledge among nurses about mechanical ventilator waveforms.

Questions of the Study

The study will try to answer the following questions:

- 1- What is the overall level of knowledge about the most common and important mechanical ventilators waveforms identification and interpretation among Palestinian nurses?
- 2- What are the most common factors that help or hinder the increasing in nurses' level of knowledge about mechanical ventilator waveforms?
- 3- How much are the educational sessions effective in increasing the level of knowledge among nurses about mechanical ventilator waveforms?

Study Hypotheses

H₀: There is no significant relationship between nurses' demographic factors (age, gender, educational level, residency... etc.) and their level of knowledge about mechanical ventilator's waveform identification and interpretation at a significance level of 0.05.

H₀: There is no significant relationship between nurses' professional factors (experience in nursing profession and intensive care unit, perceived job satisfaction... etc.) and their level of knowledge about mechanical ventilator's waveform identification and interpretation at a significance level of 0.05.

H₀: There is no significant effect of educational sessions on the level of knowledge about mechanical ventilator waveforms identification and interpretation among Palestinian nurses at a significance level of 0.05.

Chapter Two

Literature Review

This chapter includes the review of the most related articles regarding the study's topic about the effect of educational sessions on the level of knowledge and practice about mechanical ventilator's waveforms among nurses in the intensive care units (ICUs). The keywords that were used include: mechanical ventilator, waveforms, graphics, educational sessions, a synchrony. The articles that were included are full-text, original, published in English language using the scientific search engines of Google Scholar, PubMed, and other respiratory nursing management-focused journals, with a total number of 26 found articles related to the topic, ending up with 8 reviewed articles that met the inclusion criteria. In general, there is a lack in the coverage of this specific topic, where most of the articles in the area of mechanical ventilators for nursing and the educational sessions in regard to this are focused on the ventilator-associated pneumonia (VAP), and the educational sessions were more focused on VAP and mechanical ventilator basics rather than deep focus on waveform and their interpretation in terms of asynchrony (Tallo et al., 2017 ; Joshi et al., 2017 ;Geravandi et al., 2018). On the other hand, few articles were found to be related to the topic, and concludes that there is insufficient level of knowledge among nurses about recognition and interpretation of mechanical ventilators' waveforms, with various effect of educational sessions, where some concluded a positive improvement in the level of knowledge, while others stated no significant change, but the level of practice regarding the topic was significantly improved (Geravandi et al., 2018 ; Chacon et al., 2012 ; Alqahtani et al., 2020).

Level of Knowledge about Different Aspects of MV and Waveforms

One of the great advantages of using waveform analysis for mechanically ventilated patients is considering it as a noninvasive method for the purpose of patient-ventilator interaction and asynchrony identification. On the other hand, the health care providers (HCPs) need a specific set of experience to influence them to be able to work in ICUs with great confidence regarding mechanical ventilation care (Lynch-Smith et al., 2016). Ramirez et al. (2017) proposed in the beginning of their study that aimed to investigate the HCP's ability to identify patient-ventilator asynchrony (PVA) using mechanical ventilators' waveforms among ICU patients. The researchers conducted their study on a sample of 120 physiotherapists, 88 physicians and 158 nurses, by showing them three of the most commonly recognized asynchrony waveforms: double-triggering, auto-triggering and ineffective effort. Results showed that there is a significantly more PVA identification among trained HCPs (who reported receiving at least one course focused on mechanical ventilator care), where PVAs were identified by 30.4% of the trained HCPs and 9.4% of the non-trained HCPs. On the other hand, no significant differences were found between experiences (had 5 years or more of experience dealing with mechanically ventilated patients in ICU settings) and non-experienced HCPs in the determination of PVAs, where PVAs were identified correctly by 22.2% experienced vs 20.7% non-experienced. The study also concluded the importance of training and found that trained HCPs have 3.67 times more the ability to detect PVAs, while no significant difference in the detection ability was found between types of HCPs. The main advantage of the study was its fairly large sample size and variety of HCPs who were included in

the study. On the other hand, no recommendations were provided in regard to the investigation of further factors rather than the training and experience level.

Alqahtani et al. (2020) conducted similar approach of the previous study on a sample of 411 critical care HCPs, including 139 nurses, 152 respiratory therapists and 120 physicians, from 39 hospitals in Saudi Arabia. The Saudi study found similar findings in regard to the positive effect of training on the detection of PVAs, where 19.12% of the trained HCPs detected all of the PVAs compared to 3.1% for non-trained HCPs. Moreover, no significant differences were found in the determination of PVAs between experienced and non-experienced HCPs, where it was 9.74% vs 11.65%. The study also found that receiving a previous training on MV waveforms was associated with 5.41 times the ability to recognize the given PVAs compared to non-trained HCPs, while female HCPs had 1.93 times the PVAs recognition compared to males. The authors concluded the urgent need for educational programs establishment that focus on PVA detection skills, as well as the establishment of policies and guidelines of early detection and management of PVAs according to the studied data. So, the more recent study had superior advantages than the previous one in that it provided further and more specific recommendations to enhance the level of knowledge about PVAs among HCPs.

Windsor (2005) was aimed to investigate the critical care nurses' ability to interpret ventilator's graphics. The researcher conducted the study on a sample of 113 nurses and included several aspects to be identified by the nurses, including different waveforms and their identification and differentiation. Among the sampled nurses, 32 reported they received training session's specific for ventilator graphics, mainly by the hospital and the ventilator's company. Results showed that the overall level of knowledge

among nurses about MV waveforms was 40.3%, which is significantly below the satisfactory level of 60%. More specifically, level of knowledge was below satisfactory level for themes of waveform identification (26.7%), modes of ventilation (49.5%), and phenomena affecting patients' outcomes (33.9%), flow-time waveforms aspects (45.9%), waveforms differentiation (33.6%), flow-time waveforms aspects (44.6%) and pressure-time waveforms (39.1%). The researcher concluded that there is a huge need for nurses to increase their perception and level of knowledge about different aspects of MV waveforms identification and differentiation, which will help in the follow-up planning for the patients. The main limitation of this study is that we could not find the specific questionnaire that was used, which could have helped in identifying specific terms of knowledge areas that were covered.

Educational Sessions Effect on Level of Knowledge about MV Waveforms

Educational sessions, if applied correctly by trained personnel, may have positive effects on the level of perception and knowledge, as well as practice about MV's different aspects. On the other hand, several factors may play a role in the change in nurses' level of knowledge and practice regarding this topic, and this what Jansson et al. (2014) aimed to investigate in regard to the level of knowledge and practice among nurses about mechanical ventilation, focusing on the role of patient simulation strategy as the main educational method. The study utilized prospective randomized control trial (RCT) on a sample of 30 equally distributed nurses. Results found no significant difference in level of knowledge scores among the nurses in regard to the mentioned aspects after the conduction of the educational sessions using patient simulation, while, on the other hand, a significant improvement was noted in their skill scores in all aspects and at all time

points following the educational session. The conclusion of this study is that improvement can be noticed in the nurses' practice level rather than knowledge scores after conducting educational sessions, and therefore, such comparative studies should include the assessment and follow-up of nurses' practice rather than mere knowledge scoring. The main advantage in regard to this study is that the researchers conducted a systematic follow-up plan on multiple time points, which allowed to investigate for the knowledge and skills decline over time, which is recommended to be conducted in local studies.

A hypothesis regarding the potential effect of increased knowledge of MV waveforms detection among HCPs on the length of stay (LOS) of ICU patients was tested by Lynch-Smith, Thompson, Pickering, and Wan (2016) on a sample of 17 nurses and 16 respiratory therapists using a quasi-experimental pretest-posttest design. The questions that were delivered to HCPs were focused on the area of PVA determination, phases, causes and management strategies, with basic waveform analysis. Results showed a significant increase in the mean test score from 10.3 to 15.9 (p -value < 0.001) for nurses, and from 14.6 to 20.3 (p -value = 0.002) for respiratory therapists. On the other hand, no significant difference in patients' condition was noted between the two phases, according to the changes in mean APACHE II scores at admission (21 to 24.6, p -value = 0.054) and the mean days of MV (from 5.4 to 4.8, p -value = 0.54). In conclusion, educational lectures improve the level of awareness and knowledge about PVA recognition and management among critical care nurses but has no potential effect on the patients' outcomes in terms of total risk scores and LOS. The opposite was found by Bulleri, Fusi, Bambi, and Pisani (2018) who conducted a systematic review of 43 articles in regard to the PVA types, outcomes and nursing detection skills. In their review, they cited a study by Fusi et al.

(2015), who found that level of knowledge in regard to PVA has improved in their sample of nurses after 6 months of finishing the given course. Conducting studies with an approach of patient's improvement investigation is recommended according to what was found in the previous two studies, because LOS and patient's outcomes are the main goals to be improved and are sensitive topics.

Gravante et al. (2022) conducted a study in order to investigate the impact of educational and training session on the level of knowledge about MV waveforms among 19 nursing students on a 3-phase program, where level of knowledge was reassessed immediately and 1-month after the providing of educational program. Results showed that none of the nursing students was able to identify any of the MV waveforms (0.0%). Significant difference in the level of knowledge was noticed immediately after the completion of the educational program, where the mean accurate detection was 77.2%, where 78.9% of the nursing student correctly identified 4 out of the 6 provided PVAs, and 75.0% one month after the program, but the percentage of correct detection of 5 out of 6 PVAs increased to more than 50%, while there was no significant difference between the immediately and 1-month later. Researchers concluded that there is a need for more prolonged educational programs in regard to MV waveforms for nursing students to enhance their preparedness for the future profession, where the researchers stated they provided only 2 hours of the educational material, and there is a need for bigger studies that implement RCT design. The advantage of this study also includes the prolonged follow-up period.

Mohammed (2019) conducted a study to survey the knowledge level about PVA among respiratory therapists on a sample of 118 respondents in Saudi Arabia. Results

showed that only 1.7% of the participants were able to identify all of the 5 PVAs correctly, while 11.8% identified 4 PVAs, 26.1% for 3 PVAs, 20.2% for 2 PVAs and 10.1% for 1 PVA, while 30.3% failed to detect any of them. No significant difference was found in the mean number of identified PVAs between trained (2.05) and non-trained (1.60) therapists, and the same between experienced (more than 5 years, mean = 1.83) and non-experienced (mean = 1.88) therapists. More surprisingly, no significant difference was found in the mean number of correctly detected PVAs between checking the MV for one time (1.22), two times (2.06) or three times (1.80) per shift. On the other hand, therapists were asked to identify the most common difficulties they face in their workplace, and they were mostly related to lack of knowledge or experience (28.8%), lack of sedation (9.3%), lack of staff and workload (7.6%), the need for doctor's order (5.1%) and ventilator's type (4.2%) while 44.9% reported no difficulties. One of the advantages regarding this study is the investigation of the role of frequency of MV status during the shift, which is recommended to be included in further studies, because the nurses' main role is the continuous investigation of the patients' status. Also, the study investigated for the main barriers against their knowledge and practice.

Summary

Studies have found two main conclusions in regard to the education and training of health care providers (HCPs) about MV and waveform, which were the limited evidence of the continuing educational sessions' effectiveness on the patients' outcomes improvement, as well as the requirement of well-designed trials to confirm this theory about the correlation between continuous education and training in improving the outcomes and increasing the level of knowledge among nurses as crucial partition of the

HCPs (Guilhermino, Inder, & Sundin, 2018). Work in ICU setting requires interdisciplinary efforts between several specialties, and while there is nearly no application of the respiratory therapy program among Palestinian hospitals, in spite of respiratory therapy program being taught in some of the health sciences universities. The interaction between nurses and respiratory therapists is essential in correctly detecting the patients' status on MV.

Chapter Three

Methodology

This chapter includes the summary of the study's design, population and sample characteristics, inclusion and exclusion criteria, data collection and analysis process, as well as ethical considerations.

Study Design

The study is utilized using pretest-posttest quasi-experimental design, in which the researcher will provide the targeted sample of nurses with an educational session after assessing their level of knowledge and practice regarding the MV waveform analysis, and then reassess them after the educational sessions. In the true experimental studies, there are three cardinal conditions: randomization, control, and intervention, while in the quasi-experimental design the randomization is lost for the purpose of time and cost effectiveness in the first place.

The main advantage of the quasi-experimental design is that they do not interrupt natural context and avoid the artificial threats of the trials. Moreover, the use of quasi-experimental design has been increased during the last period of time as policymakers conduct such studies to implement health interventions of the demonstrated causal effects of their activities on the health sectors (Bärnighausen, et al. 2017).

Site and Setting

The current study is conducted in the ICU and cardiac care unit (CCU) departments of Palestine Medical Complex – Ramallah. The hospital is suitable for the current study because it includes a number of experienced nurses as well as novice nurses

in the field of ICU and dealing with mechanical ventilators, as well as having a continuous education department which facilitates the educational session providing for nurses.

Palestine Medical Complex (PMC) is the largest governmental hospital in Palestine, and was established in 1963, with a current capacity of more than 250 beds, and more than 800 employees, including around 350 nurses (practical, registered and midwives). Its original name was “Ramallah Governmental Hospital” and was renamed to PMC in 2010. It currently has several buildings, with each building holding a set of specialties, which are: Ramallah Sons Building, Sheikh Zayed Building for emergency and orthopedic departments, Bahrani Building for pediatric specialties, Kuwaiti Building for specialized and cardiopulmonary surgeries, as well as Hemodialysis and Blood Bank buildings.

Currently, PMC holds five adult ICUs, two at the old building for adult medical and surgical cases, as well as medical cardiac cases (CCU) in the same building, with one surgical CCU and neuro-surgery ICU inside the Kuwaiti Building, resulting in a total capacity of 42 beds for adult ICUs, The Bahrani Building also holds 2 neonatal ICUs and one pediatric ICU.

Population, Sample and Sampling

The study population includes all of ICU nurses in the targeted hospitals, regardless to their gender, educational level, or professional role.

Convenience sampling method is selected to recruit the nurses to be enrolled in the study, as the study is quasi-experimental, by which the researcher will conveniently select the nurses who are on their duty when presenting in the ICUs one nurse after another. The total number of nurses in the targeted departments is 100 nurses, and using G*Power 3.1.9.7 software, with a power of 0.95, $\alpha = 0.05$, effect size = 0.5 and a matched

pair type of test, the recommended sample size is 54 nurses, as shown in the following Figure.

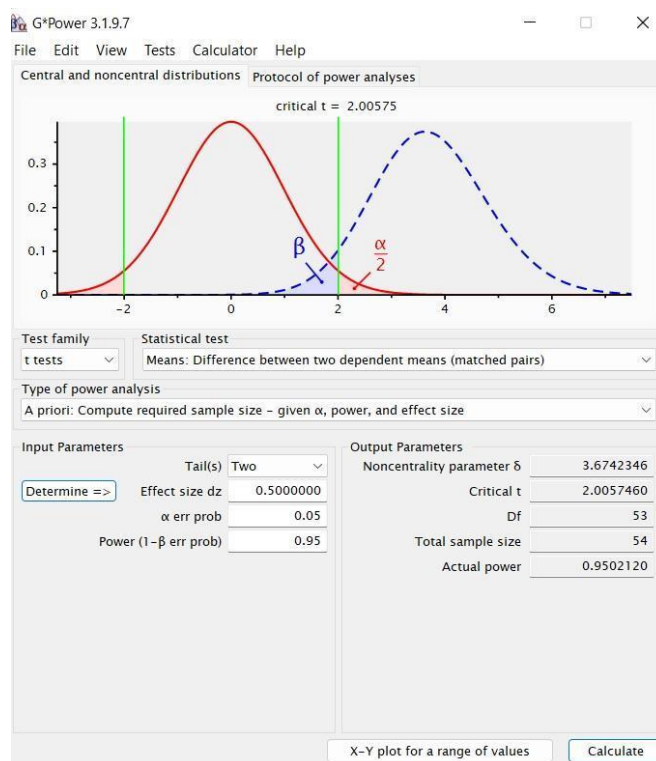


Figure 9: in previous study for Lynch-Smith et al., 2016 sample size was 33.

Inclusion and Exclusion Criteria

All full-time nurses with an experience of more than 6 months in ICU or CCU setting and/or dealing with MVs who accept to participate in the study, regardless to age, gender, or professional position, will be included in the study.

On the other hand, nurses with part-time job working outside the targeted departments, who have an experience of less than 6 months in the ICU or CCU settings and/or MVs or who left the study and did not complete the posttest phase, have been excluded from the participation.

Study Variables

Independent variables: Educational Sessions and nurses' sociodemographic variables.

Dependent variable: Ventilator Waveforms Knowledge

Data Collection Tool and Process of Educational Sessions

After granting the approval of participation from the enrolled nurses, a self-administered questionnaire that was developed by the researcher based on previous literature is used to collect data regarding nurses' level of knowledge and practice about MV waveforms recognition and interpretations, as a pre-interventional phase. The data collection tool includes three major parts: Socio demographic data (age, gender, professional and MV-related experience, socioeconomic status, perceived satisfaction ... etc.), level of knowledge about general and specific aspects of MV and waveforms recognition and interpretation, and level of practice about MV waveforms analysis and interpretation (Windsor,S 2005) .

After collecting data in the pre-interventional phase, the intervention of educational session is provided to the enrolled nurses as a PowerPoint lecture over 6 hours in May 2023 that is well-prepared based on up-to-date evidence and provided by ICU doctor specialist (Dr. Dina abu jaber) with a high level of experience in critical care and MVs.

The post-interventional phase includes the reassessment of the second and third parts of the data collection tool for the same nurses, with a slight difference in the context and difficulty of questions.

Questionnaire Assessment

Revising tests on the basis of test scores is an essential part of improving instruction. Therefore, we evaluated the difficulty level, discrimination level, and quality of the 4 response options or alternatives on fifteen multiple-choice questions that were used to measure nurses' MV waveform knowledge, for e.g., (Haladyna, 1999; Labeau et al. 2007).

- ▶ The difficulty level of an item or a question equals the percentage of respondents who answer the question correctly. Possible values range from 0 to 100%.
 - Items with values less than 10% are considered very difficult (i.e., items answered correctly by less than 10% of the respondents).
 - Items with values more than 90% are considered very easy (i.e., items answered correctly by more than 90% of the respondents).
- ▶ The item discrimination (*ID*) level indicates of whether an item or a question can distinguish between high and low performers, with 27% of respondents in each group. The respondents were divided into high performers and low performers. The *ID* index was computed as follows:

$$ID = \frac{N_H - N_L}{N_H + N_L} \times 100\%, \text{ where}$$

N_H = Number of correct answers in the high performer group,

N_L = Number of correct answers in the low performer group.

- Possible values range from -100% to 100% (values less than 15% are bad, values from 15% to 25% are satisfying/mediocre, values from 25% to 35% are good, and values of 35% or higher are very good).
- ▶ The quality of a response alternative equals the percentage of respondents who choose the alternative.

- Possible values range from 0 to 100%. Alternatives with a value of 0 are not attractive, and those with a value of 100% might be very attractive.

Table 1 summarizes item analysis findings on the pretest phase. The values for item difficulty and discrimination were very good to satisfying. From item difficulty analysis it seems that question 5 (Waveform detection of “cycling”; value 72.2%) was the easiest question. Question 8 (Difference between active and passive expiration; value 19.4%) was the more difficult one. The analysis of item discrimination showed that question 10 (Constant vs decelerating flow in ARDS; value 89.5%) was the best in distinguishing between respondents with high and low performance, while question 7 (Waveform detection of “true square wave”; value 23.1%) was the worst one. Nevertheless, all these values are acceptable, suggesting no items should be excluded. In the analysis of the quality of the response alternatives, none had values of 0.0, suggesting that these options are suitable, and no reformulation should be considered.

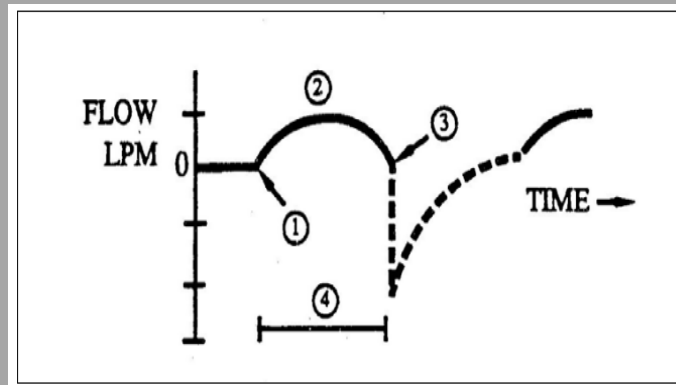
Table 1: Pretest phase Nurses' responses on 15 questions related to MV waveforms knowledge (N = 72, correct answers are in bold)

Questions/Items	Item difficulty (%)	Quality of the option (%)	Item discrimination (%)
<i>Question 1: The stage in a process when the inspiratory valve opens and gas flow is initiated, and can be time- or patient-activated, refers to:</i>			
1. Time-patient ratio	54.2	16.7	42.9
2. Flow		25.0	
3. Trigger		54.2	
4. Pressure-flow curve		4.2	
<i>Question 2: If the mechanical ventilator repeatedly initiated breath cycles related to reaching the sensitivity threshold for an abnormal reason, like a leak in the endotracheal tube, it refers to:</i>			
1. Auto-PEEP	45.8	23.6	44.0
2. Auto-cycling		45.8	
3. PRVC (Pressure-regulated volume-controlled)		12.5	
4. Negative pressure		18.1	
<i>Question 3: For a patient with a set I:E ratio of 1:2 attached to a MV on assist-control mode at a set respiratory rate of 12 breath/min, the expiratory phase would take:</i>			
1. 1.67 seconds	29.2	19.4	25.0
2. 3.33 seconds		29.2	
3. 2 seconds		47.2	
4. 1 second		4.2	

Question 4: The speed in which the gas enters and leaves the mechanical ventilator's valves is called:

1. Flow	50.0	50.0	75.0
2. Tidal volume		19.4	
3. Ventilation		18.1	
4. Ventilation-perfusion matching		12.5	

Regarding the following figure, which illustrates the flow pattern of a spontaneous breath, answer **Question 5** and **Question 6**



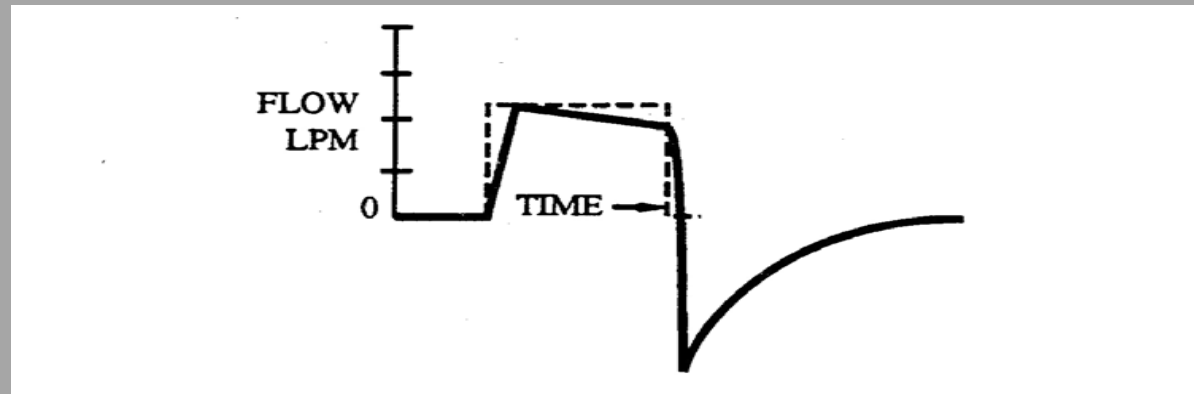
Question 5: The point numbered (3) refers to:

1. The magnitude of inspiratory flow	72.2	8.3	84.6
2. Trigger		9.7	
3. Cycling (end of inspiration)		72.2	
4. Inspiratory flow duration		9.7	

Question 6: The point numbered (1) refers to:

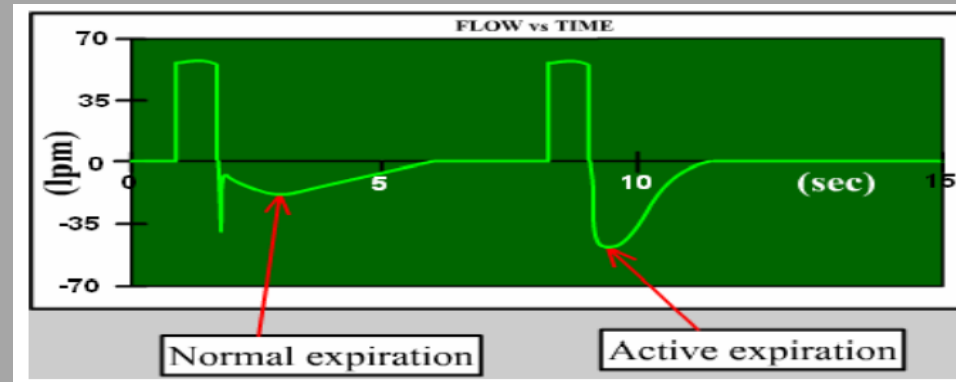
1. Trigger	56.9	56.9	33.3
2. Cycling		2.8	
3. Magnitude of inspiratory		23.6	
4. Inspiratory flow duration		16.7	

Question 7: The following figure illustrates a superimposed (مترابك) waveform over the dotted line. What does the dotted line represent for a patient who is attached to a controlled breathing mode?



1. Peak airway pressure	23.6	34.7	23.1
2. True square wave		23.6	
3. Inspiratory pause		34.7	
4. Peak flow mode		6.9	

Question 8: The following figure illustrates the difference between normal (passive) and active expiration, what is the key difference between them?

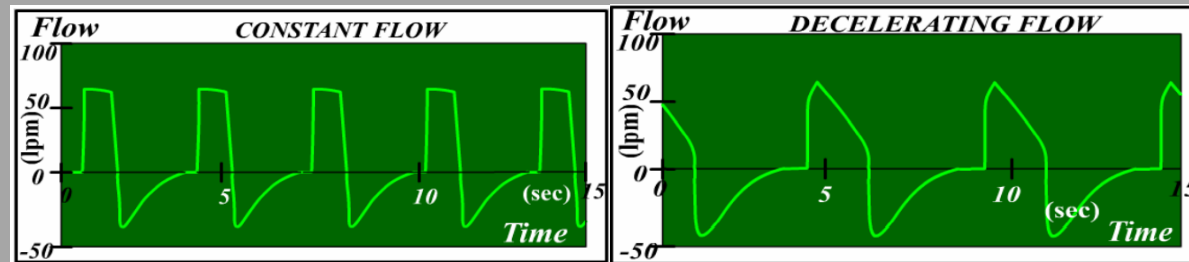


1. The active expiration results in more effort from the patient because it requires shorter time.		19.4	
2. Normal expiration results in better emptying of the lungs because it depends on the patient's lung elasticity.		29.25	
3. During the active expiration, the peak expiratory pressure increases, which results in shorter expiratory time.	19.4	37.5	27.3
4. There is no need for a help from the abdominal muscles to push more air outside the lungs by pushing further the diaphragm upwards.		13.9	

Question 9: How do the length and internal diameter of the endotracheal tube affect the airflow of the air from and to the mechanical ventilator?

1. Thicker tubes allow more secretions to accumulate, and therefore decreases flow	51.4	9.7	34.5
2. Longer tubes allow more reach to carina, and therefore increasing flow sufficiency to the lungs		25.0	
3. Thinner and longer tubes result in higher resistance, and therefore decreased flow		51.4	
4. No specific relationship between diameter and length of the tube and the flow is known		13.9	

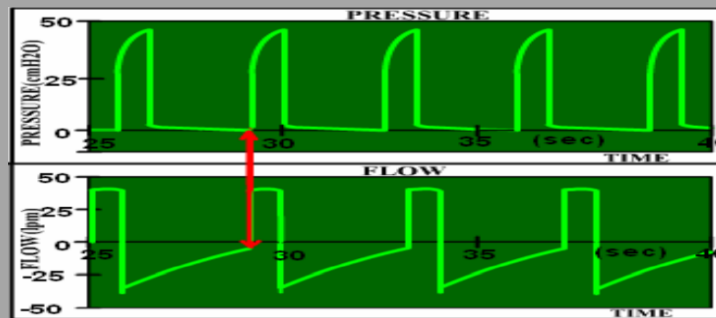
Question 10: In a case of an acute respiratory distress syndrome ARDS, is there a difference in the oxygenation between the constant flow (left) and decelerating flow (right)?



1. In the constant airflow, air is delivered in a shorter time, which allows the air to enter with higher pressure, and therefore optimizes gas exchange		11.1	
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2. In the decelerating airflow, there is a shorter expiration time, which may lead to a risk of air-trapping, and therefore increasing the oxygenation	58.3	16.7	89.5
3. In the decelerating airflow, there is more time allowed for the inspiratory phase, which allows for more time for gas exchange, and therefore improving oxygenation.		58.3	
4. No specific relationship was found between the airflow type and oxygenation		13.9	

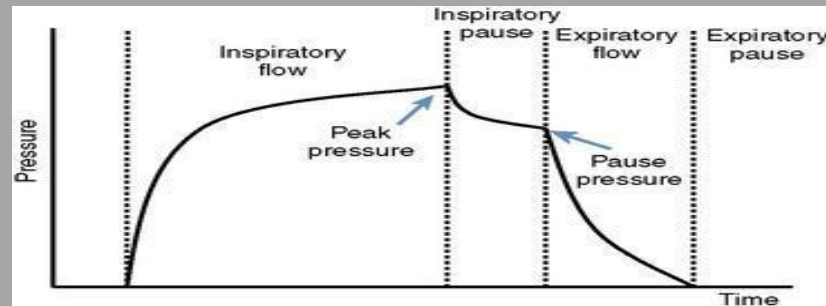
Question 11: The following figure illustrates pressure- and flow-time waves. Why would the figure indicate the presence of auto-PEEP?



1. The expiratory (negative flow) is not enough for the air to get out of the lungs, and therefore it leads to auto-PEEP		22.2	
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2. The inspiratory time is too short, which allows more air to enter the lungs, and therefore more air trapped, resulting in auto-PEEP		29.2	
3. The flow-time wave shows that the flow did not return to baseline, which indicates that the next controlled inspiratory phase interrupted the expiration, and therefore there was no complete gas exhalation.	43.1	43.1	33.3
4. The information provided in the figure is not enough.		5.6	

Question 12: During the inspiratory pause (as illustrated in the following figure), an important parameter is measured. It refers to:

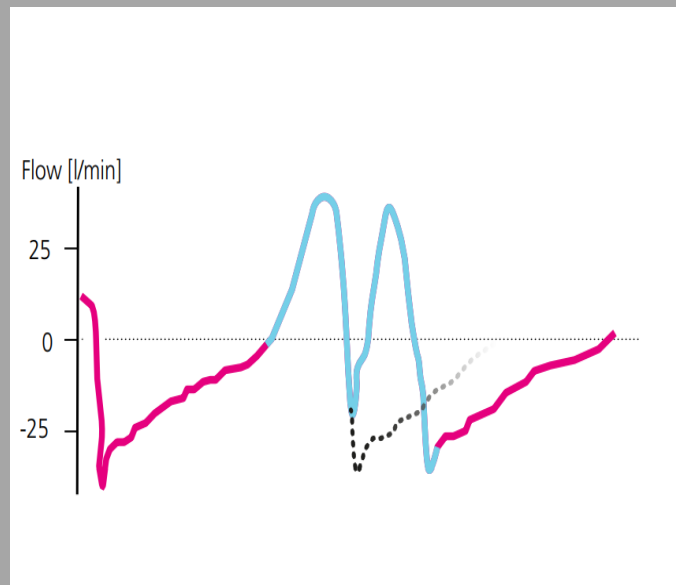


1. Peak airway pressure (PIP)		23.6	
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2. I:E ratio	43.1	12.5	60.0
3. PEEP		20.8	
4. Plateau pressure		43.1	

*Related to the following waveforms in **Question 13** and **Question 14**, what do they indicate in terms of patient-ventilator asynchrony? (Focus on the blue line, taking in consideration the dotted line is the normal expected flow when there is a good synchrony)*

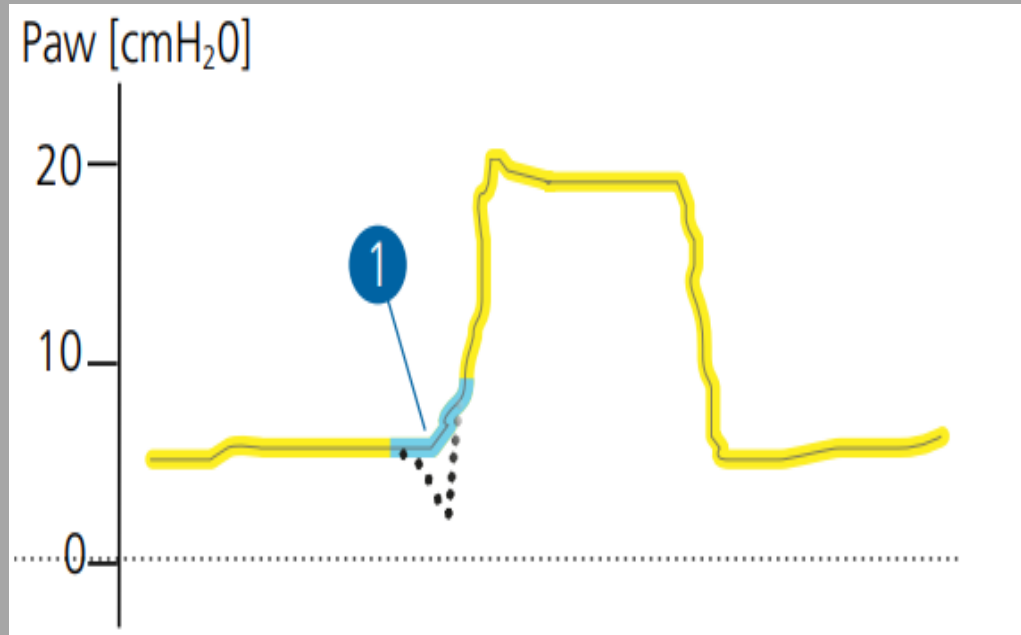
Question 13:



1. Delayed cycling		29.2	
2. Early cycling		11.1	

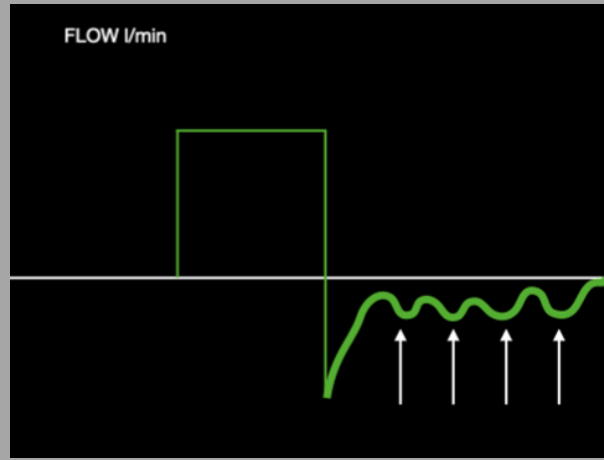
3. Double trigger	44.4	44.4	68.4
4. Auto-triggering		15.3	

Question 14:



1. Delayed cycling		25.0	
2. Early cycling		26.4	
3. Double trigger	33.3	15.3	23.8
4. Auto-triggering		33.3	

Question 15: The following waveform represents what is known as “oscillatory waveform”, which is an abnormal waveform that may be witnessed during expiratory phase. What could be the possible reason behind it?



1. Insufficient PEEP set up on the ventilator	30.6	18.1	55.6
2. Presence of fluid in the ventilator's circuit		30.6	
3. Patient's cough or increased intrathoracic pressure		36.1	
4. The wave is an artifact and can be neglected		15.3	

Validity and Reliability

The validity of the data collection tool is granted by reviewing the tool by 5 experts in critical care nursing and MVs, including 2 faculty doctors, 2 highly experienced nurses and 1 pulmonologist. The feedback is used to craft the questions in a way that is understandable for all nurses' levels of education and experience, as well as the recommendation of using close-ended questions. One of the experts recommended that we must change the answer 13. While the others agreed with all the questions.

For reliability, test-retest was the most suitable reliability grant for the current tool, which is done as the study implemented pretest-posttest design. For test-retest reliability, the correlation coefficient was calculated, and the result was 0.975, which is higher than the cut point of 0.80, and therefore, the reliability of the used tool in the current study is acceptable.

Data Analysis

SPSS version 26 (Statistical Package for Social Sciences) software was used for data analysis. Graphical displays (e.g., Q-Q plots) and normality tests (e.g., Shapiro-Wilk) were used to assess if quantitative variables were normally distributed, while Levene's test was used to assess the homogeneity of variance. Descriptive results include frequencies, mean, standard deviation and minimum and maximum values for all the variables included in the data collection tool. The data were approximately normally distributed with equal variances, so parametric inferential tests were conducted to investigate the relationships and differences between independent and dependent variables (e.g., nurses' sociodemographic and knowledge score), as well as the significance in pretest-posttest differences, using the suitable test, mainly paired sample t-test, independent sample t-test, Chi-square test, and one-way analysis of variance

(ANOVA). Finally, a multivariate linear regression was performed to determine the significant predictors of the pretest-posttest mean difference in MV waveform knowledge level among participants. A p-value ≤ 0.05 was considered statistically significant.

Ethical Considerations

The study and data collection process are committed to ethical principles that the Arab American University Review Board has, in which the approval from the university and Ministry of health is granted before starting the data collection process. Also, the approval of participation from nurses is granted by signing an informed consent that is attached to the data collection tool as a first page, with no collection of the nurse's name, and replacing this with a serial number and a contact method to be able to reach the nurse for the posttest phase. Moreover, the informed consent includes the mentioned facts, as well as that all collected information are used merely by the researcher and for research purposes only and ensuring the nurse's right to withdraw from the study at any time without the need to declare any reason. Lastly, the study does not include invasive intervention or a trial, as the intervention includes the educational session only.

Chapter Four

Results

This chapter analyzes the descriptive and analytical findings of the current study. The descriptive findings include the frequencies and percentages of the categorical demographic information of the study's nurses who took part and their responses to the questions.

Concerning MV waveforms, the mean and standard deviation (SD) of the numerical variables of demographic data, and the general level of understanding of MV waveforms. The investigation of the variations in knowledge of the MV waveform between the study's pretest and posttest phases, as well as the influence of nurses' demographic characteristics on this degree of knowledge, are also included in the analytical results.

Part 1: Demographic data

The following table (Table 1.1) distributes the demographic data of the nurses who participated in the current study. The table shows that the mean age of the nurses was 28.44 ± 4.75 years old, ranging from 22 to 42 years old, with 38.9% of them are between 26 and 30 years old, followed by 33.3% between 22 and 25 years old, with more than one quarter (27.8%) of them are older than 30 years. It also showed that the percentages of male and female nurses were identical (50% each), with more than half of them (58.3%) are living in rural areas, followed by 36.1% living in urban areas. Moreover, more than half of the nurses (59.7%) are married, while the rest of them (40.3%) are single, mostly living in a good perceived socioeconomic status (63.9%).

Most of the participated nurses (58.3%) hold the bachelor's degree in nursing, while the rest of them holding postgraduate degrees (41.7%) and are majorly working in general ICU settings (72.2%). The mean experience level in the nursing profession of the sampled nurses was 6.34 ± 4.33 years, ranging from 1 to 20 years of experience, with more than half of them (54.2%) having an experience of 1 to 5 years, compared to a mean experience in the ICU settings of 4.66 ± 3.63 years, that ranged from 1 to 14 years, with 70.8% of the nurses having between 1 and 5 years of ICU experience. Lastly, the majority of the nurses (77.8%) stated they have not received a prior training or lecturing on the topic of MV waveforms interpretation.

Table 1.1: Descriptive results of the nurses' demographic data (N = 72)

Characteristic	Categories	n (%)
Age (years)	22 – 25	24 (33.3)
	26 – 30	28 (38.9)
	> 30	20 (27.8)
	Mean \pm SD (min – max)	28.44 ± 4.75 (22 – 42)
Gender	Male	36 (50.0)
	Female	36 (50.0)
Residency	City	26 (36.1)
	Village/Camp	46 (63.9)
Social status	Single	29 (40.3)
	Married	43 (59.7)
Socioeconomic status	Excellent	11 (15.3)
	Good	46 (63.9)
	Fair/Poor	15 (20.8)
Educational level	Bachelor's degree	42 (58.3)
	Postgraduate	30 (41.7)
ICU type	General ICU	52 (72.2)
	Others (CCU/PICU/NICU)	20 (27.8)
Experience in nursing (years)	1 – 5	39 (54.2)
	6 – 10	18 (25.0)
	> 10	15 (20.8)
	Mean \pm SD (min – max)	6.34 ± 4.33 (1 – 20)

Experience in ICU settings (years)	1 – 5	51 (70.8)
	> 5	21 (29.2)
	Mean \pm SD (min – max)	4.66 \pm 3.63 (1 – 14)
Prior MV waveform training	Yes	16 (22.2)
	No	56 (77.8)

Part 2: Level of knowledge regarding MV waveforms

The first table in this part (Table 2.1) distributes the frequencies and percentages of the nurses' responses to the question related to their level of knowledge about MV waveforms, and, in general, it shows an overall increase in the percentages of correct answers of all questions from the pretest to posttest phases, where the percentage of correct answers ranged between 19.4% to 72.2% in the pretest phase compared to a range of 44.4% to 91.7% in the posttest phase.

Table 2.1: Distribution of nurses' correct responses to questions related to MV waveforms knowledge (N = 72)

Questions and correct answers	Pretest	Posttest
	n (%)	n (%)
<i>Question 1: The stage in a process when the inspiratory valve opens and gas flow is initiated, and can be time- or patient- activated, refers to:</i>		
Trigger	39 (54.2)	59 (81.9)
<i>Question 2: If the mechanical ventilator repeatedly initiated breath cycles related to reaching the sensitivity threshold for an abnormal reason, like a leak in the endotracheal tube, it refers to:</i>		
Auto-cycling	33 (45.8)	48 (66.7)
<i>Question 3: For a patient with a set I:E ratio of 1:2 attached to a MV on assist-control mode at a set respiratory rate of 12 breath/min, the expiratory phase would take:</i>		
3.33 seconds	21 (29.2)	64 (88.9)
<i>Question 4: The speed in which the gas enters and leaves the mechanical ventilator's valves is called:</i>		
Flow	36 (50.0)	62 (86.1)
<i>Regarding the following figure, which illustrates the flow pattern of a spontaneous breath, answer Question 5 and Question 6</i>		

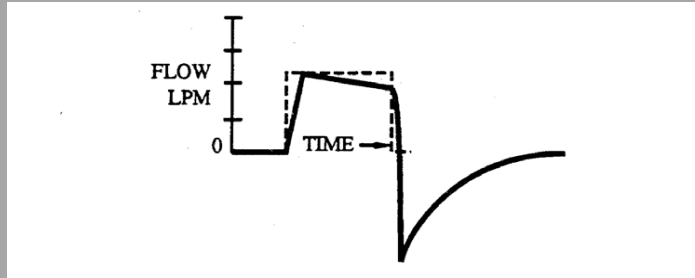
Question 5: The point numbered (3) refers to:

Cycling (end of inspiration)	52 (72.2)	64 (88.9)
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Question 6: The point numbered (1) refers to:

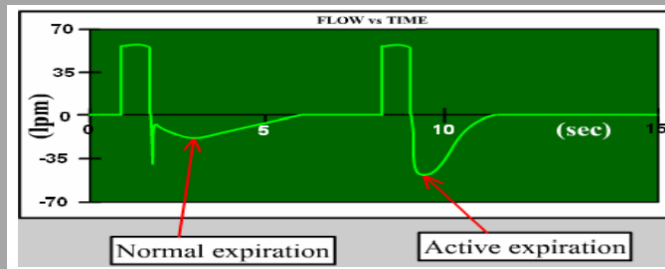
Trigger	41 (56.9)	58 (80.6)
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Question 7: The following figure illustrates a superimposed (متراكب) waveform over the dotted line. What does the dotted line represent for a patient who is attached to a controlled breathing mode?



True square wave	17 (23.6)	34 (47.2)
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Question 8: The following figure illustrates the difference between normal (passive) and active expiration, what is the key difference between them?



The active expiration results in more effort from the patient because it requires shorter time	14 (19.4)	32 (44.4)
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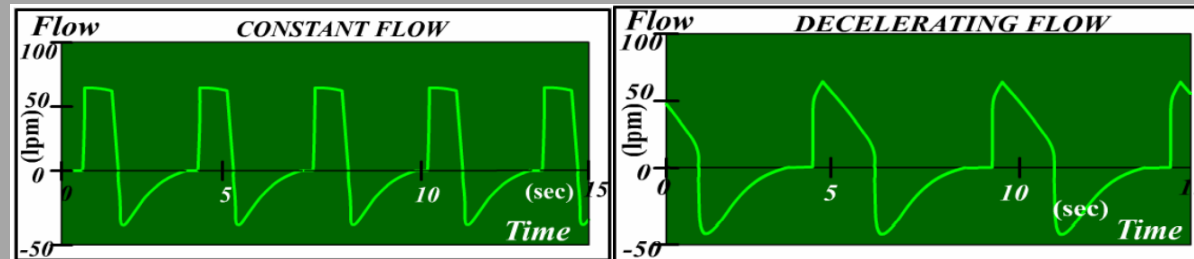
Question 9: How do the length and internal diameter of the endotracheal tube affect the airflow of the air from and to the mechanical ventilator?

Thinner and longer tubes result in higher resistance, and therefore decreased flow

37 (51.4)

66 (91.7)

Question 10: In a case of an acute respiratory distress syndrome ARDS, is there a difference in the oxygenation between the constant flow (left) and decelerating flow (right)?

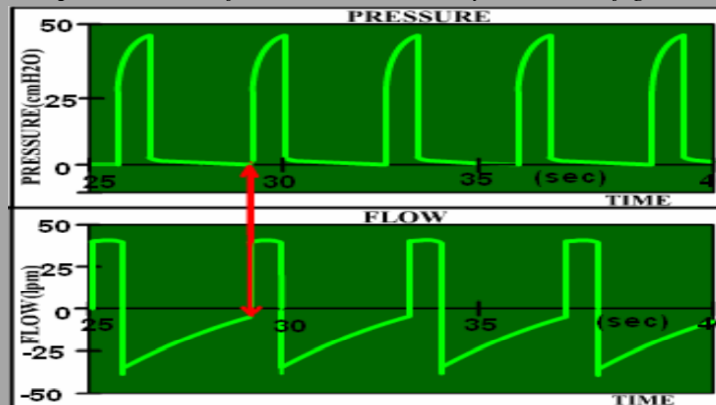


In the decelerating airflow, there is more time allowed for the inspiratory phase, which allows for more time for gas exchange, and therefore improving oxygenation

42 (58.3)

43 (59.7)

Question 11: The following figure illustrates pressure- and flow-time waves. Why would the figure indicate the presence of auto-PEEP?

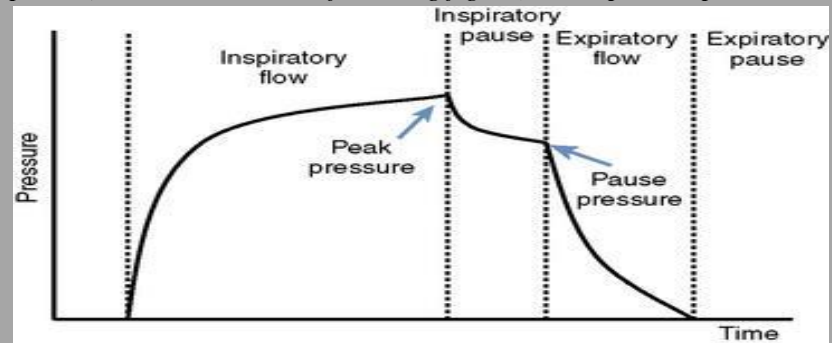


The flow-time wave shows that the flow did not return to baseline, which indicates that the next controlled

31 (43.1)

44 (61.1)

Question 12: During the inspiratory pause (as illustrated in the following figure), an important parameter is measured. It refers to:



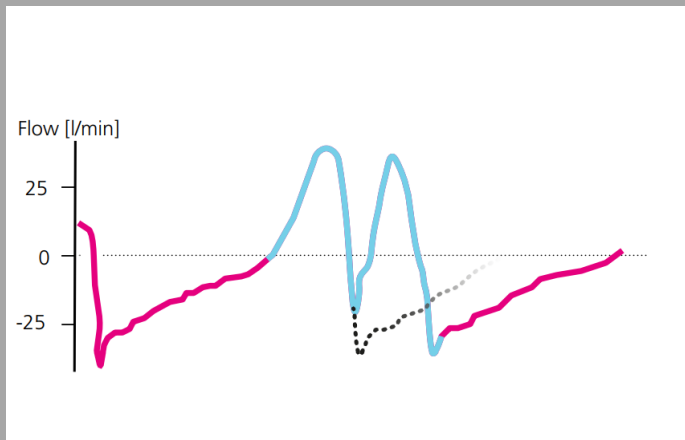
Plateau pressure

31 (43.1)

41 (56.9)

Related to the following waveforms in **Question 13** and **Question 14**, what do they indicate in terms of patient-ventilator asynchrony? (Focus on the blue line, taking in consideration the dotted line is the normal expected flow when there is a good synchrony)

Question 13:

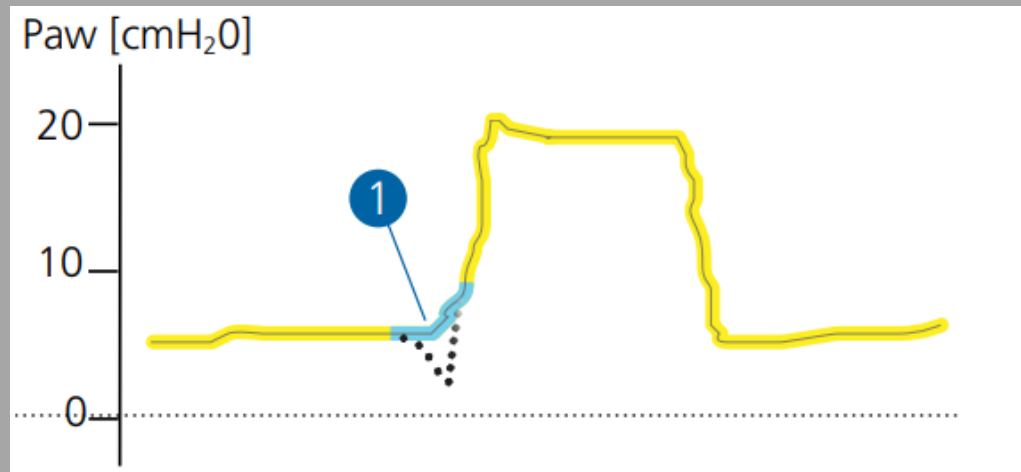


Double trigger

32 (44.4)

44 (61.1)

Question 14:

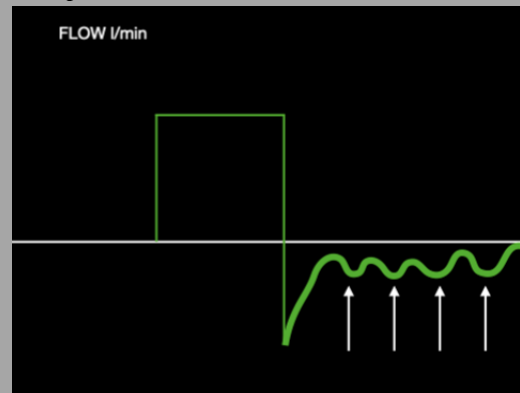


Auto-triggering

24 (33.3)

32 (44.4)

Question 15: The following waveform represents what is known as “oscillatory waveform”, which is an abnormal waveform that may be witnessed during expiratory phase. What could be the possible reason behind it?



Presence of fluid in the ventilator's circuit

22 (30.6)

36 (50.0)

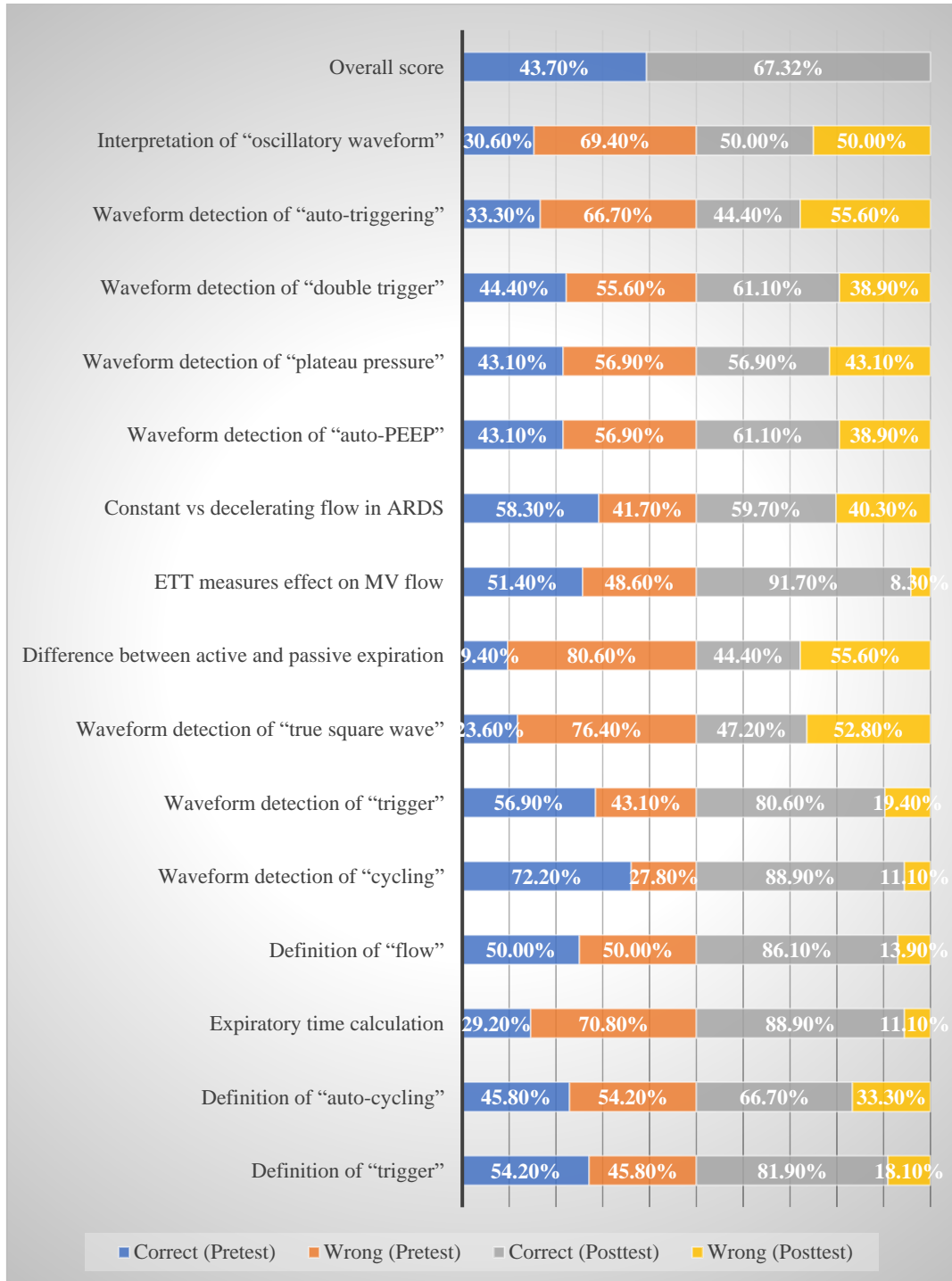


Figure 2.1: Differences in correct answers between pretest and posttest phases regarding waveform level of knowledge

The following table (Table 2.2) investigates the significance of the differences in correct answers percentages between pretest and posttest phases. It showed that the increase in correct answers between pretest and posttest phases was significant in topics

related to definitions of trigger (54.2% vs 81.9%, p-value < 0.001), auto-cycling (45.8% vs 66.7%, p-value = 0.012) and flow (50.0% vs 86.1%, p-value < 0.001), as well as the waveform detection of cycling (72.2% vs 88.9%, p-value = 0.012), trigger (56.9% vs 80.6%, p-value = 0.002), true square wave (23.6% vs 47.2%, p-value = 0.003), auto-PEEP (43.1% vs 61.1%, p-value = 0.030) and double triggering (44.4% vs 61.1%, p-value = 0.045), while the detection of plateau pressure (43.1% vs 56.9%, p-value = 0.096) and auto-triggering (33.3% vs 44.4%, p-value = 0.171) had no significant increase.

The significant improvement was also noticed in topics related to I:E ratio-based calculations, in which the calculation of expiratory time correct answers increased from 29.2% to 88.9% (p-value < 0.001). Also, the interpretation of the difference between normal (active) and passive expiration increased in success from 19.4% to 44.4% (p-value = 0.001), as well as the knowledge of the effect of ETT's diameter and length on the flow of MV (51.4% vs 91.7%, p-value < 0.001) and the interpretation of oscillatory waveform (30.6% vs 50.0%, p-value = 0.017), while the differentiation between constant and decelerating flow among ARDS patients did not significantly improve (58.3% vs 59.7%, p-value = 0.865). Overall, Table 2.3 showed that the mean number of correct answers significantly increased from a mean of 6.556 ± 2.50 to 10.097 ± 2.48 out of 15, reflecting an increase in the percentage of scores from a mean of $43.704\% \pm 16.67\%$ to $67.315\% \pm 16.53\%$, from the pretest to posttest phases, respectively.

Table 2.2: Differences in the distribution of correct answers between pretest and posttest phases regarding the level of knowledge about MV waveforms

Question and topic	Pretest	Posttest	X^2	p-value
	n (%)	n (%)		
Definition of “trigger”	39 (54.2)	59 (81.9)	12.777	< 0.001*
Definition of “auto-cycling”	33 (45.8)	48 (66.7)	6.349	0.012*
Expiratory time calculation	21 (29.2)	64 (88.9)	53.092	< 0.001*
Definition of “flow”	36 (50.0)	62 (86.1)	21.594	< 0.001*
Waveform detection of “cycling”	52 (72.2)	64 (88.9)	6.384	0.012*
Waveform detection of “trigger”	41 (56.9)	58 (80.6)	9.341	0.002*
Waveform detection of “true square wave”	17 (23.6)	34 (47.2)	8.774	0.003*
Difference between active and passive expiration	14 (19.4)	32 (44.4)	10.350	0.001*
ETT measures effect on MV flow	37 (51.4)	66 (91.7)	28.677	< 0.001*
Constant vs decelerating flow in ARDS	42 (58.3)	43 (59.7)	0.029	0.865
Waveform detection of “auto-PEEP”	31 (43.1)	44 (61.1)	4.703	0.030*
Waveform detection of “plateau pressure”	31 (43.1)	41 (56.9)	2.778	0.096
Waveform detection of “double trigger”	32 (44.4)	44 (61.1)	4.012	0.045*
Waveform detection of “auto-triggering”	24 (33.3)	32 (44.4)	1.870	0.171
Interpretation of “oscillatory waveform”	22 (30.6)	36 (50.0)	5.658	0.017*
X^2 : Pearson Chi-square test statistic value (*): The relationship is significant (i.e., p-value < 0.05)				

Table 2.3 showed that the mean number of correct answers significantly increased from a mean of 6.556 ± 2.50 to 10.097 ± 2.48 out of 15, reflecting an increase in the percentage of scores from a mean of $43.704\% \pm 16.67\%$ to $67.315\% \pm 16.53\%$, from the pretest to posttest phases, respectively.

Table 2.3: Inferences about differences from the pretest and the posttest phases regarding the level of knowledge about MV waveforms

Overall knowledge score	Pretest		Posttest		Paired T-test	p-value
	Out of 15	%	Out of 15	%		
Mean \pm SD	6.556 \pm 2.500	43.703 \pm 16.667	10.097 \pm 2.479	67.315 \pm 16.527	- 54.141	< 0.001*
(*): The difference is significant (i.e., p-value < 0.05)						

The next table (Table 2.4) investigated the significance of differences in both pre- and post-test scores of MV waveform knowledge according to the nurses' demographic and professional factors. The results revealed that ICU nurses who were older in age significantly had higher knowledge scores than younger ages in both pretest (p-value = 0.019) and posttest (p-value = 0.039) phases. Furthermore, ICU experience had a significant impact on the knowledge scores in both pretest (p-value = 0.004) and posttest (p-value = 0.004) phases, where higher experience was associated with higher knowledge levels. On the other hand, nurses in general ICU departments had lower mean knowledge scores than nurses in other departments (CCU, PICU, and NICU) in pretest phase (p-value = 0.046), while the differences in the posttest phase were not statistically significant in the posttest phase (p-value = 0.055). Lastly, the differences in the mean knowledge scores in both pretest and posttest phases were not statistically significant according to the rest factors: gender, residency, social status, socioeconomic status, education level, ICU type, experience in nursing, and prior MV waveform training, (i.e., p-value > 0.05).

Table 2.4: Differences in mean knowledge about MV waveforms according to nurses' demographic and professional factors in pretest and posttest phases (N = 72)

Factors	Categories	Pretest		Posttest	
		Mean \pm SD	p-value	Mean \pm SD	p-value
Age (years)	22 – 25	36.11 \pm 13.18	0.019*	60.56 \pm 14.16	0.039*
	26 – 30	46.43 \pm 16.18		69.52 \pm 16.37	
	> 30	49.00 \pm 18.52		72.33 \pm 17.48	
Gender	Male	46.11 \pm 17.92	0.223	69.07 \pm 17.47	0.370
	Female	41.30 \pm 15.19		65.56 \pm 15.57	
Residency	City	41.79 \pm 17.74	0.469	65.64 \pm 17.46	0.522
	Village/Camp	44.78 \pm 16.13		68.26 \pm 16.10	
Social status	Single	40.00 \pm 15.01	0.122	64.14 \pm 15.27	0.182
	Married	46.20 \pm 17.42		69.46 \pm 17.17	
Socioeconomic status	Excellent	41.82 \pm 11.19	0.185	65.45 \pm 12.23	0.139
	Good	46.23 \pm 17.91		70.00 \pm 17.26	
	Fair/Poor	37.33 \pm 14.86		60.44 \pm 15.63	
Educational level	Bachelor's degree	42.70 \pm 14.36	0.549	66.98 \pm 14.65	0.842
	Postgraduate	45.11 \pm 19.63		67.78 \pm 19.11	
ICU type	General ICU	41.28 \pm 16.49	0.046*	65.00 \pm 16.38	0.055
	Others: CCU/ PICU/ NICU	50.00 \pm 15.82		73.33 \pm 15.75	
Experience in nursing (years)	1 – 5	40.68 \pm 15.95	0.162	64.10 \pm 15.72	0.140
	6 – 10	44.81 \pm 16.46		68.89 \pm 16.65	
	> 10	50.22 \pm 17.79		73.78 \pm 17.36	
Experience in ICU settings (years)	1 – 5	40.13 \pm 14.94	0.004*	63.79 \pm 15.33	0.004*
	> 5	52.38 \pm 17.80		75.87 \pm 16.53	
Prior waveform training	Yes	47.08 \pm 16.23	0.361	69.58 \pm 16.68	0.537
	No	42.74 \pm 16.81		66.67 \pm 16.58	

(*): The difference is significant (i.e., p-value < 0.05)

Lastly, multiple linear regression was performed to determine the significant predictors of the pretest-posttest differences in mean level of MV waveform knowledge among the nurses. The estimated model was summarized in Table 2.5. Although all the independent variables explained about 17% of the total variation in pretest-posttest differences in mean level of MV waveform knowledge scores, the overall model was not significant. Furthermore, none of the demographic factors were significantly associated with pretest-posttest differences in mean level of MV waveform knowledge scores (i.e., p -value > 0.05), and thus, the improvement of level of knowledge was regardless to the nurses' characteristics, indicating an improvement of knowledge level for all nurses' levels.

Table 2.5: Predictors of the pretest-posttest differences mean difference in MV waveform knowledge level among participants using multiple linear regression model (N = 72)

Independent Variables		<i>B</i>	<i>p</i> -value	95% confidence interval for <i>B</i>	
				Lower bound	Upper bound
Age	26 – 30 ^a	-1.852	0.181	-4.591	0.888
	> 31 ^a				
Gender	Male	-3.023	0.239	-0.8112	2.065
Residency	Village/Camp	-1.239	0.247	-3.362	0.883
Social status	Married	-0.743	0.475	-2.812	1.327
Socioeconomic status	Good ^b	-0.658	0.622	-3.315	1.998
	Excellent ^b	0.287	0.816	-2.172	2.745
Education	Postgraduate	-0.213	0.899	-3.539	3.113
ICU type	CCU, PICU, and NICU	-1.610	0.105	-3.566	0.345
Nursing experience	> 10 ^c	0.169	0.882	-2.089	2.427
	6 – 10 ^c	2.561	0.297	-2.311	7.432
ICU experience	> 5	2.488	0.094	-0.436	5.411
Waveform training	Yes	0.560	0.726	-2.619	3.739
		-0.803	0.513	-3.245	1.639
Model summary		$R^2 = 0.170$, Adjusted $R^2 = 0.016$, and $F = 0.914$ (p -value = 0.545)			

Note: (a): Reference category: 22 – 25; (b): Reference category: Fair/Poor; (c): Reference category: 1 – 5
B: Unstandardized regression coefficients, R^2 : Multiple determination coefficient

Chapter Five

Discussion

In the following chapter, the researcher discusses the results and content of the current study, which was based on the comparison of the results with the findings of previous studies, as well as providing a critique of the results and other content of the study from the researcher's point of view.

The researcher in the current study succeeded in trying to recruit ICU nurses who are representative to the overall ICU nursing population. First, most of the nurses in the current study were in the age groups of 22 – 25 (33.3%) and 26 – 30 (38.9%) years old, which is the age range that most ICU nurses are actually working at, with older nurses tend to leave ICU settings and convert to working in less effort demanding departments. Also, the researcher succeeded in recruiting the sample with one-to-one ratio in terms of gender, as well as accurate representation of the nurses according to their educational level (most of them, 58.3%, hold the bachelor's degree in nursing), with increased trend in acquiring postgraduate degrees (41.7%), especially in young generations, which is supported by the increased availability of critical care nursing specialties in the Palestinian universities, which results in more advanced knowledge, skills and more positive attitude of ICU nurses regarding several critical care topics, including areas related to respiratory management and MV and waveforms comprehension and interpretation.

Most of the recruited nurses were working in general ICU settings (72.2%), which is also representative to the targeted population, as this category included medical, surgical, and neuro-surgical ICU settings, that represent most of the ICU nursing

workforce. Lastly, most of the nurses in the current study sample did not receive prior MV waveform training (77.8%), neither via the hospitals they work at nor outside them, which was suitable for the current study, as it supports the idea that ICU nurses are in need for more knowledge and practice related to MV waveforms interpretation and management, as was also discussed in the statement of the problem of the current study. On the other hand, nurses who did and did not receive prior MV waveform training did not have significant differences in terms of the mean increase in interpretation skills between pretest and posttest phases, which indicates that the provided educational session was beneficial to all the nurses, regardless to their demographic, professional or knowledge basis, as discussed later.

The tool that was used to evaluate nurses' competency in MV waveform interpretation in the current study was developed by the researcher depending on previous literature, mainly the study of Windsor (2005), which is also a master thesis that was conducted with the aim of building an educational program related to MV waveforms, starting from the basics and reaching the advanced areas in interpretation and management. In the current study, the researcher picked 15 of the most representing questions from the previous literature and tried to cover as much topics as possible related to MV waveforms, which were variant in easiness and covered most of the scenarios that ICU nurses may face during their experience. The used tool was also reviewed by specialists in the area of ICU nursing and MV management, including an intensivist, which gives the tool a further advantage.

The main result of the current study was related to the significant increase in level of knowledge about MV waveform interpretation among the nurses from a mean of

43.703% to 67.315% (p -value < 0.001), which highlights the importance of covering such a topic, because it showed poor pretest level of knowledge, which significantly improved in the posttest phase. Also, the use of quasi-experimental design (pre-post design) to test the study's hypothesis was the most suitable design, as it allowed the researcher to compare pretest and posttest scores of knowledges in a quantitative way.

The results also showed that ICU nurses who were older in age significantly had higher knowledge scores than younger ages in both pretest and posttest phases (p -value = 0.019 and 0.039, respectively). Furthermore, ICU experience had a significant impact on the knowledge scores in both pretest and posttest phases (p -value = 0.004 in both), where higher ICU experience was associated with higher knowledge levels. On the other hand, nurses in general ICU departments had lower mean knowledge scores than nurses in other departments (CCU, PICU, and NICU) in pretest phase (p -value = 0.046), while the differences in the posttest phase were not statistically significant in the posttest phase (p -value = 0.055). Finally, none of the sociodemographic factors were significantly associated with pretest-posttest differences in mean level of MV waveform knowledge scores, which indicates that educational impact on the posttest scores of MV waveforms knowledge was unified for all nurses despite their demographic or professional factors.

In comparison with the current study, the previous study of Ramirez et al. (2017) focused on three of the most common PVAs, which were auto-triggering, double-triggering and ineffective effort, which the current study also assessed in the knowledge tool, where double-triggering witnessed a significant increase in level of knowledge from pretest to posttest phases (44.4% to 61.1%, respectively, p -value = 0.045), while the knowledge insignificantly increased for the concept of auto-triggering (from 33.3% to

44.4%, respectively, p -value = 0.171), while the concept of ineffective effort, which was presented in the current study by the terms of triggering as definition and waveform detection, also witnessed increased knowledge from 54.2% and 56.9%, respectively, in the pretest phase to 81.9% and 80.6%, respectively (p -value < 0.05). The previous study emphasized the role of educational sessions in the increased confidence of ICU nurses and other HCPs in the detection and management of MV waveforms. On the other hand, the difference between the current and previous studies was mainly related to larger sample size and inclusion of multiple specialties in the previous study, which was more difficult in the current study, while it had more rigorous methodological approach, rather than cross-sectional design.

The same applies for the Saudi study of Alqahtani et al. (2020), which was more recent, but also included several specialties, while nurses accounted for 139 out of 411 of the sample size, and this is considered a limitation for the previous study, because nurses represent higher percentages among HCPs in critical care settings. On the other hand, it is recommended to conduct future studies in Palestine that includes various HCPs, with suitable representation of nurses related to other HCPs, and trying to apply the same quasi-experimental design, which has several advantages over the cross-sectional or retrospective designs. In opposite to the previous study, which found a significant difference in level of knowledge regarding PVAs between HCPs who received and did not receive training about PVAs, the current study found no significant difference in knowledge scores between who received and did not receive training regarding overall MV waveforms in pretest and posttest phases. The difference can be related to the inclusion of several specialties in the previous study, as well as larger sample size, but mainly related to the questioning about three main PVAs in the previous study, while the

current study included 15 different questions related to MV waveforms, including definitions, scenarios and waveform detection skills, and this gives the current study the superiority over the previous one. Moreover, the nurses in the current study had significantly higher pretest scores in terms of PVAs that were discussed in the previous study than all HCPs who were included in it, which can be related to the higher involvement of nurses in respiratory management and nursing care related to MV waveform among the Palestinian nurses than Saudi nurses, in which Saudi nurses are from multiple nationalities.

In the previous study of Windsor (2005), the researcher stated that 28.3% (32 out of 113 nurses) have received prior training related to MV waveforms interpretation, which is relatively higher than in the current study (22.2%), while it is considered that the percentages of nurses who received prior training is low in both settings, which highlights the need for more educational sessions related to this topic in different hospitals and countries. In parallel with the findings of the previous study, the current study also found unsatisfactory level of knowledge during the pretest phase regarding MV waveforms (40.3% vs 43.704%, respectively), which supports the need for educational sessions, but the previous study did not conduct a pretest-posttest design to allow for comparison in the impact of educational sessions, which was found to be significant in the current study, while the previous study as the basis for the current study in defining the most common terms and areas to be focused on during the knowledge assessment and education sessions, including waveform identification, ventilation modes, affecting factors, and different waveform types, which all has higher scores in the current study compared to the previous one. The differences may be related to a major point that the researcher of the current study thought about, which is the impact of nurses' experiences during the

COVID-19 pandemic that increased the nursing involvement in the management and interpretation of MV modes and waveforms. Also, there are specific differences in the demographic characteristics between nurses of both studies.

Although the previous study of Jansson et al. (2014) was conducted using a randomized controlled trial methodology, and using multiple-point follow up of knowledge and skills assessment, the current study has some advantages over it, including larger sample size, and focusing on a specific areas of mechanical ventilation knowledge, which are waveforms. On the other hand, there was significant difference between both studies, which is the absence of any demographic factor's impact on the level of knowledge about mechanical ventilation, which was found to be the opposite in the pretest phase of the current study, which can be related to the main difference in the way of educational approach, which was patient stimulation strategy in the previous study, compared to conventional lecturing method in the current study, and therefore, the difference between both studies in that no significant difference in knowledge scores were noted in the previous study, while the current study found a significant difference in knowledge scores, the significance of educational session impact may be related to the reliance on a highly experienced specialist to provide and present the educational session, which allowed for better delivery of information related to MV waveforms, as well as allowing the nurses to freely discuss the provider. Additionally, the previous study successfully investigated the impact of educational sessions on the skill level of nurses related to mechanical ventilation, which was limited in the current study by the limited time, although detection skills of waveforms were measured in the current study using close-ended questions that were supported by graphical illustrations, while the method of

actual interpretation of waveforms on real patients and scenarios give a superior presentation of actual nursing skills.

The previous study of Lynch-Smith et al. (2016) was conducted with a secondary aim to evaluate the nurses' increased knowledge and skills of MV waveforms detection on patients' outcomes, including APACHE scores and LOS, which is a powerful method that measures the actual impact of nursing role on patients' outcomes. While the previous study found no significant impact of nurses' increased knowledge about MV waveform detection and patients' outcomes, both studies share a common result, in which there was a significant increase in level of knowledge and skills after receiving educational sessions. Also, the previous study stated that both pretest and changes in knowledge scores among respiratory therapists were higher than among nurses, which indicates the significant role and importance of having respiratory therapists inside the ICU settings, which is absent in most of the Palestinian hospitals. Also, the previous study supports the idea that such methodological approaches should be applied in the Palestinian literature with the focus on patients' outcomes, which is limited also by the need for more time of investigation, as patients' outcomes assessment may need several months and large count of admissions to notice the difference, as well as the presence of several confounding variables that may play a role in the impact of patients' outcomes, like the nature of diseases and patient characteristics.

The proper level of knowledge about MVs and their waveforms identification and management skills among nurses starts with proper educational curriculum during the college period, and therefore, the study of Gravante et al. (2022) opens the minds to the importance of applying a similar approach of the current study on a sample of nursing

students, especially after receiving the related topics in the college, which is mostly done during the third academic year, specifically in the course of critical care nursing, which is supported by the clinical training, as applied in majority of nursing colleges in Palestine, while most of them started to apply more modern ways of education, including simulation laboratories and virtual reality (VR) methods. Such modern methods may also be used for nurses in their orientation programs during the first phases of employment and are in need of assessing their impact in future studies, in accordance with the global trend of research. Also, another factor that is in need for assessment among nurses on the MV waveforms knowledge is the number of waveforms that the nurse is exposed to during each shift, which was investigated by the study of Mohammed (2019).

Conclusion

The level of knowledge and skills related to MV waveforms among nurses is important to be identified and improved, especially with the increased demand of mechanical ventilation management among nurses in the ICU settings, as well as the increased percentages of nurses who acquire higher education degrees in critical care specialties. The main aim of the current study was to assess the level of knowledge about MV waveforms among Palestinian ICU nurses, as well as the impact of educational sessions on it. The researcher utilized a quasi-experimental design on a sample of 72 ICU nurses (mean age = 28.44 ± 4.75 years old) and conducted an educational session that was provided by a specialist, with the assessment of pretest and posttest knowledge using a self-administered questionnaire that was developed based on previous literature. Analysis was conducted using SPSS and with full commitment to ethical principles of anonymity and confidentiality.

Among the nurses, 50% were males, 58.3% with bachelor's degree and with a mean experience of 6.34 ± 4.33 years in nursing and 4.66 ± 3.63 years in ICU settings, 22.2% of them received prior related training. Main results found an unsatisfactory level of knowledge prior to the educational session (mean = $43.704\% \pm 16.67\%$) which was significantly increased to a satisfactory level (posttest mean = $67.315\% \pm 16.53\%$, p-value < 0.001). Nurses who were older in age significantly had higher knowledge scores than younger ages in both pretest and posttest phases (p-value = 0.019 and 0.039 respectively). Nurses with higher ICU experience was associated with higher knowledge levels in both pretest and posttest phases (p-value = 0.004 in both). No significant impact of any demographic or professional factor on the mean pretest-posttest knowledge differences (p-value > 0.05). The researcher recommends conducting further studies with the inclusion of multiple specialties, as well as multiple follow up points.

Recommendations

The researcher recommends the following after discussing the study's results:

1. one policy and one practice will be recommended in hospitals which submissive to ministry of health.
2. Increase the focus of university and college curricula on the topic of MV and waveforms detection and interpretation skills for nursing students, because proper preparation of students in their early academic years is associated with better application and comprehension during their professional phase.
3. Conduct further studies in Palestine on the same topic with some methodological modifications that may make them more rigorous, including multiple points of follow up, inclusion of skill assessment of MV waveform detection, and asking more about

the relationship between specific waveforms and patients' outcomes, using scenario presentation.

4. Include multiple specialties of HCPs in future studies, which will help in better understanding of the overall healthcare services' comprehension and interpretation of MV waveforms in Palestine, as well as allowing the comparison of knowledge between them. This will also allow to probe the efforts of educational programs related to MV waveforms topics to be more specific for each specialty.
5. Conduct studies that include several patient outcomes as dependent variables of the increased knowledge and skills of nurses about MV waveforms.

Limitations

- 1- The recruitment of nurses was not randomized, which was limited by the inability to recruit all the randomly selected nurses at one specific time to assess pretest knowledge and receive the educational session, and therefore, convenient sampling method was used.
- 2- Generalization of finding weren't feasible related to restricted setting.
- 3- Limited time frame related to master thesis requirements and academic pressure, which may have helped in collecting other specialties, assessing other factors and outcomes, as well as covering more topics in the educational sessions rather than MV waveforms for the beneficial effects among nurses.

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Appendices

Appendix 1

Facilitation paper

Arab American University
Faculty of Graduate Studies



الجامعة العربية الأمريكية
كلية الدراسات العليا

2022/6/22

حضرة السادة وحدة البحث العلمي والتعليم الصحي / وزارة الصحة الفلسطينية المحترمين
الدكتور عبدالله القواسمة المحترم

تسهيل مهمة بحثية

تحية طيبة وبعد،

تهديكم كلية الدراسات العليا في الجامعة العربية الأمريكية أطيب التحيات، وبالإشارة الى الموضوع اعلاه، تشهد كلية الدراسات العليا في الجامعة أن الطالبة روان علي محمد سعدي والتي تحمل الرقم الجامعي 202012235 هي طالبة ماجستير في برنامج العناية المكثفة وتعمل على رسالة الماجستير الخاصة بها بعنوان:

" The Impact of educational sessions on ventilator waveforms knowledge among Palestinian ICU nurses " تحت اشراف الدكتور عماد أبو خضر، نأمل من حضرتكم الإيعاز لمن يلزم لمساعدتها للحصول على المعلومات اللازمة للدراسة، علماً أن المعلومات ستستخدم لغاية البحث فقط وسيتم التعامل معها بغاية السرية، وقد أعطيت هذه الرسالة بناءً على طلبها.

وتفضلوا بقبول فائق الاحترام

عميد كلية الدراسات العليا

د. نوار قطيب



Page 1 of 1

Appendix 2

Study tool (questionnaire)

The Impact of Educational Sessions on Mechanical Ventilator Waveforms' knowledge among Palestinian ICU Nurses: Quasi-experimental Study

Dear nurse,

Thank you for participating in this study that aims to investigate the level of knowledge, as well as the impact of educational sessions, among ICU nurses about mechanical ventilators' waveforms, which is a part of fulfillment of the master's degree in critical care nursing at Arab American University. Your participation is worthy as it provides us with the up-to-date information about ICU nurses' level of knowledge and limitations in regard to mechanical ventilators' waveforms, which will help in future plans to enhance ICU nurses' practice with mechanically ventilated patients.

This questionnaire consists of four major parts: 1st part is about your sociodemographic and professional data, 2nd part is about level of knowledge and practice regarding mechanical ventilators' waveform recognition and analysis before providing the educational session, while the 3rd part is the re-evaluation of your level of knowledge and practice after receiving the educational session. Lastly, the 4th part consists of nurses' evaluation of the educational material.

We ensure that the collected data are treated in an anonymous and confidential way, no name will be collected, while a contact information is needed to re-evaluate the level of knowledge after the educational session. The collected data will be used by the researcher and for research purposes only, and you can withdraw from the study at any time without the need to declare any specific reason.

For inquiries, please contact the study principal investigator: Rawan Ali Saadi,
RN

Phone number: +972533997704

e-mail

address:

rawan.sa92@gmail.com

Under the supervision of: Dr. Imad Abu Khader

Part One: Sociodemographic and professional data

Question	Answers
1- Age (in completed years)	
2- Gender	1. Male 2. Female
3- Residency	1. City 2. Village 3. Camp
4- Social status	1. Single 2. Married 3. Widowed/divorced
5- Socioeconomic status	1. Excellent 2. Good
	3. Fair 4. Bad
6- Educational level	1. Bachelor degree 2. Master degree
	3. PhD degree
7- Experience in nursing profession	Years
8- Experience in ICU settings	Years
9- ICU setting type	1. General ICU 2. CCU
10- Did you receive a training about mechanical ventilators' waveforms?	1. Yes
	2. No

Part Two: Level of knowledge about mechanical ventilators' waveforms and interpretation

Please answer the following multiple-choice questions by choosing only ONE answer regarding each question

Question 1: *The stage in a process when the inspiratory valve opens and gas flow is initiated, and can be time- or patient- activated, refers to:*

- a- Time-patient ratio
- b- Flow
- c- Trigger
- d- Pressure-flow curve

Question 2: *If the mechanical ventilator repeatedly initiated breath cycles related to reaching the sensitivity threshold for an abnormal reason, like a leak in the endotracheal tube, it refers to:*

- a- Auto-PEEP
- b- Auto-cycling
- c- PRVC (Pressure-regulated volume-controlled)
- d- Negative pressure

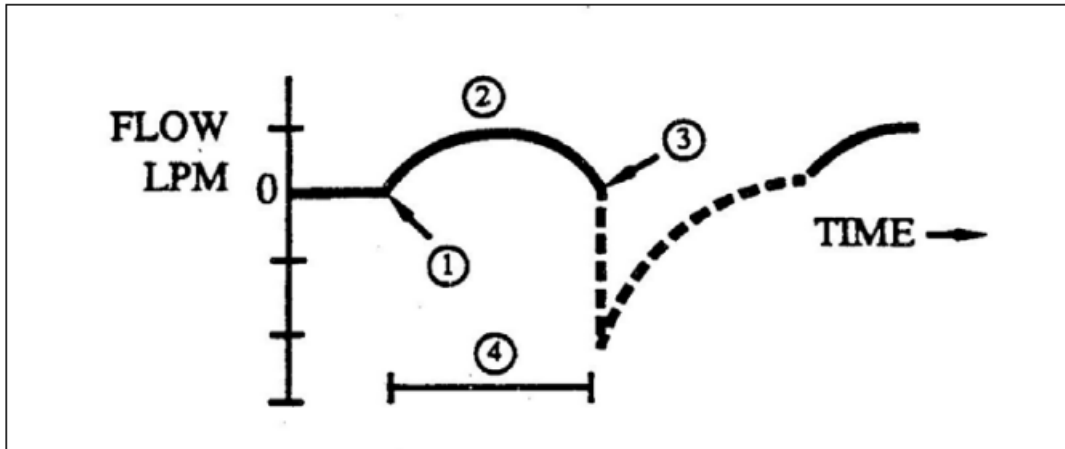
Question 3: *For a patient with a set I:E ratio of 1:2 attached to a MV on assist-control mode at a set respiratory rate of 12 breath/min, the expiratory phase would take:*

- a- 1.67 seconds
- b- 3.33 seconds
- c- 2 seconds
- d- 1 second

Question 4: *The speed in which the gas enters and leaves the mechanical ventilator's valves is called:*

- a- Flow
- b- Tidal volume
- c- Ventilation
- d- Ventilation-perfusion matching

Regarding the following figure, which illustrates the flow pattern of a spontaneous breath, answer **Question 5** and **Question 6**



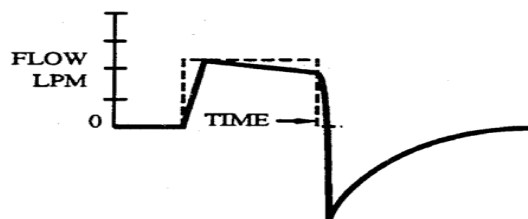
Question 5: The point numbered (3) refers to:

- a- The magnitude of inspiratory flow
- b- Trigger
- c- Cycling (end of inspiration)
- d- Inspiratory flow duration

Question 6: The point numbered (1) refers to:

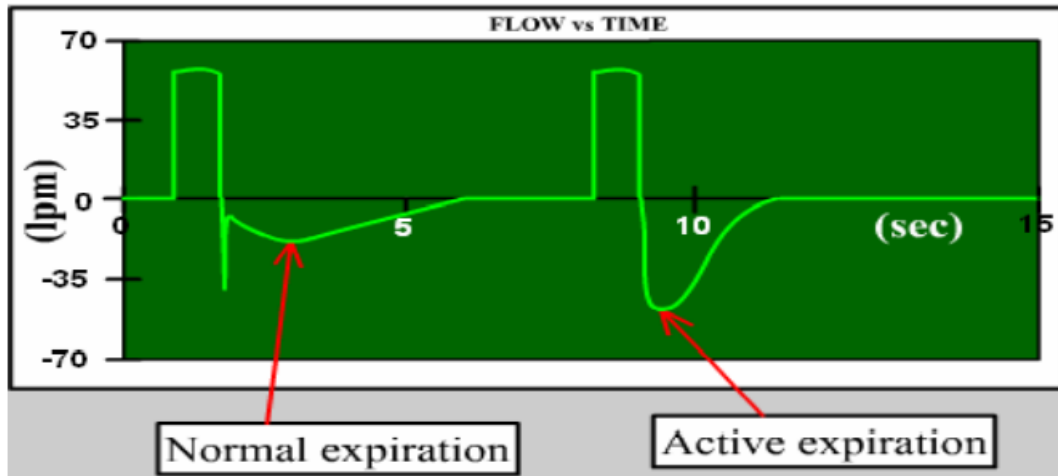
- a- Trigger
- b- Cycling
- c- Magnitude of inspiratory
- d- Inspiratory flow duration

Question 7: The following figure illustrates a superimposed (متراكب) waveform over the dotted line. What does the dotted line represent for a patient who is attached to a controlled breathing mode?



- a- Peak airway pressure
- b- True square wave
- c- Inspiratory pause
- d- Peak flow mode

Question 8: The following figure illustrates the difference between normal (passive) and active expiration, what is the key difference between them?

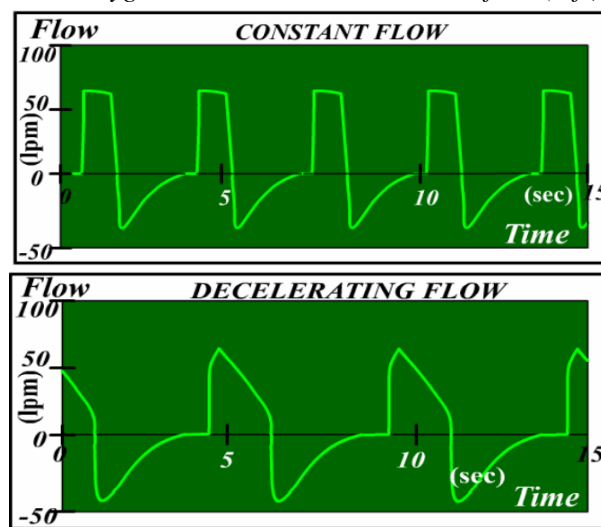


- The active expiration results in more effort from the patient because it requires shorter time.
- Normal expiration results in better emptying of the lungs because it depends on the patient's lung elasticity.
- During the active expiration, the peak expiratory pressure increases, which results in shorter expiratory time.
- There is no need for a help from the abdominal muscles to push more air outside the lungs by pushing further the diaphragm upwards.

Question 9: How do the length and internal diameter of the endotracheal tube affect the airflow of the air from and to the mechanical ventilator?

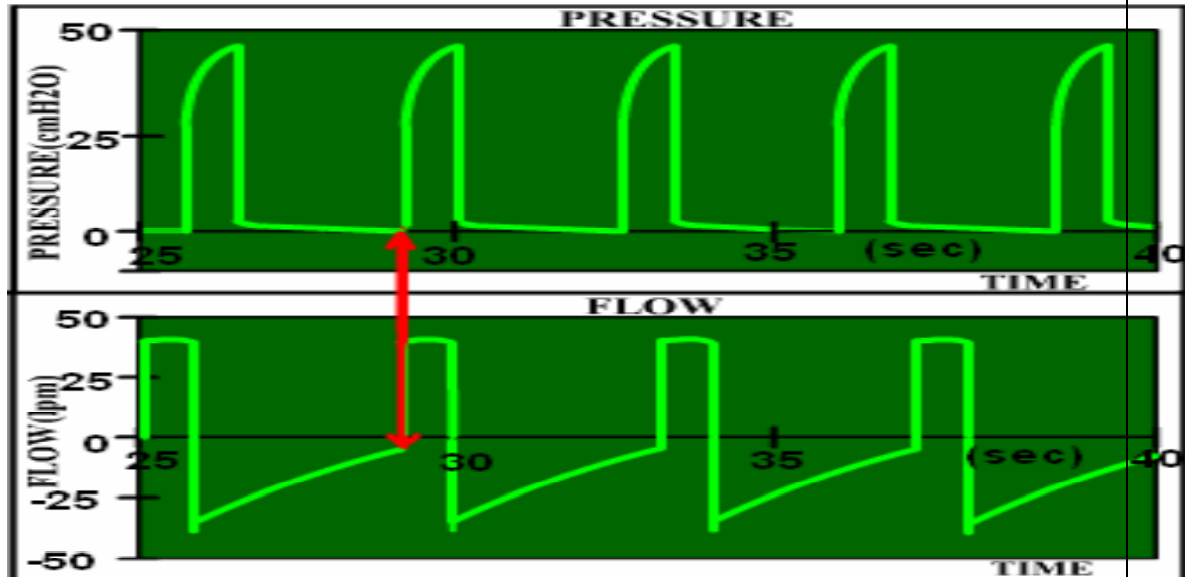
- Thicker tubes allow more secretions to accumulate, and therefore decreases flow.
- Longer tubes allow more reach to carina, and therefore increasing flow sufficiency to the lungs
- Thinner and longer tubes result in higher resistance, and therefore decreased flow.
- No specific relationship between diameter and length of the tube and the flow is known

Question 10: In a case of an acute respiratory distress syndrome ARDS, is there a difference in the oxygenation between the constant flow (left) and decelerating flow (right)?



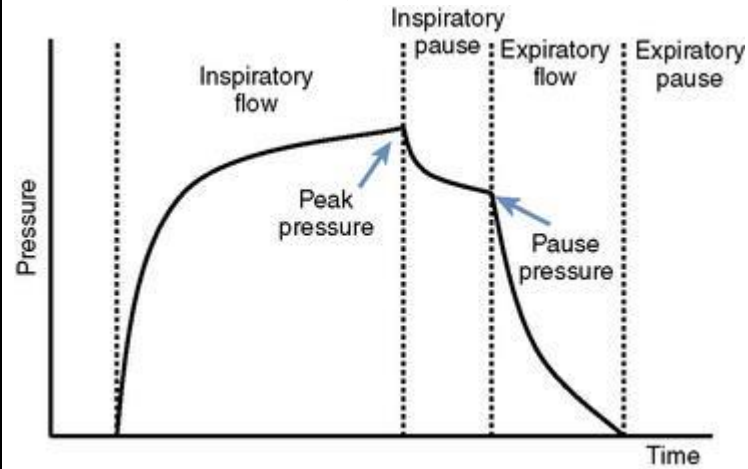
- a- In the constant airflow, air is delivered in a shorter time, which allows the air to enter with higher pressure, and therefore optimizes gas exchange.
- b- In the decelerating airflow, there is a shorter expiration time, which may lead to a risk of air-trapping, and therefore increasing the oxygenation.
- c- In the decelerating airflow, there is more time allowed for the inspiratory phase, which allows for more time for gas exchange, and therefore improving oxygenation.
- d- No specific relationship was found between the airflow type and oxygenation

Question 11: The following figure illustrates pressure- and flow-time waves. Why would the figure indicate the presence of auto-PEEP?



- a- The expiratory (negative flow) is not enough for the air to get out of the lungs, and therefore it leads to auto-PEEP.
- b- The inspiratory time is too short, which allows more air to enter the lungs, and therefore more air trapped, resulting in auto-PEEP.
- c- The flow-time wave shows that the flow did not return to baseline, which indicates that the next controlled inspiratory phase interrupted the expiration, and therefore there was no complete gas exhalation.
- d- The information provided in the figure is not enough.

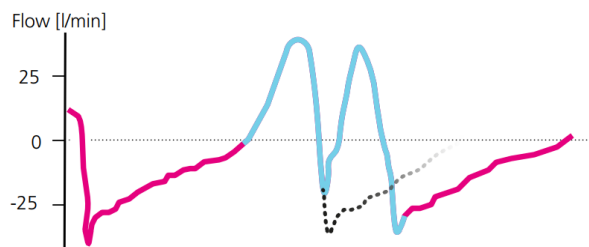
Question 12: During the inspiratory pause (as illustrated in the following figure), an important parameter is measured. It refers to:



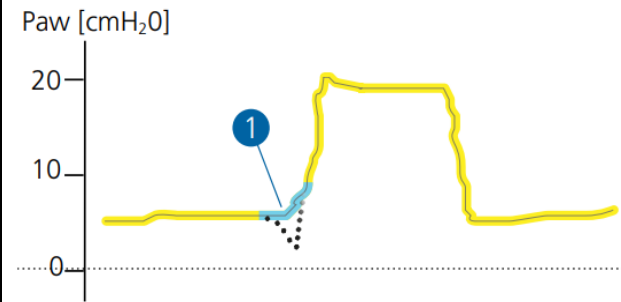
- a- Peak airway pressure (PIP)
- b- I:E ratio
- c- PEEP
- d- Plateau pressure

Related to the following waveforms in **Question 13** and **Question 14**, what do they indicate in terms of patient-ventilator asynchrony? (focus on the blue line, taking in consideration the dotted line is the normal expected flow when there is a good synchrony)

Question 13:

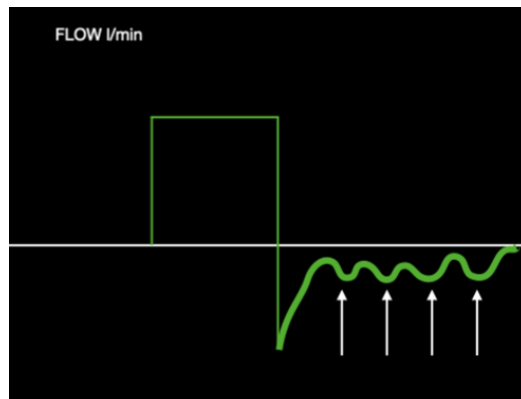


- a- Delayed cycling
- b- Early cycling
- c- Double trigger
- d- Auto-triggering

Question 14:

- a- Delayed cycling
- b- Early cycling
- c- Double trigger
- d- Auto-triggering

Question 15: The following waveform represents what is known as “oscillatory waveform”, which is an abnormal waveform that may be witnessed during expiratory phase. What could be the possible reason behind it?



- a- Insufficient PEEP set up on the ventilator.
- b- Presence of fluid in the ventilator’s circuit
- c- Patient’s cough or increased intrathoracic pressure.
- d- The wave is an artifact and can be neglected

Part Three: Nurses' feedback regarding the educational session about mechanical ventilators' waveforms

Please select one of the choices regarding the following statements that aim to investigate your feedback regarding the educational session that was provided to you about mechanical ventilator waveforms and the performance of the educator. (SA = Strongly agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly disagree).

Statement	SA	A	N	D	SD
1- The learning package was valuable for me					
2- The content of the session was up-to-date					
3- The theory of the content reached my expectations					
4- The content improved my knowledge level about mechanical ventilators and waveform					
5- The content improved my decision-making skills regarding patients on mechanical ventilators					
6- My confidence increased regarding the participation with doctors about mechanical ventilators settings					
7- I can safely adjust mechanical ventilators' settings according to the waveform analysis and arterial blood gases findings					
8- I am more encouraged to search more about mechanical ventilator waveforms topics					

9- The educator provided the content in an easy-to-digest way that helped increasing level of knowledge					
10- The educator provided the chance to discuss the content and answer our questions					

Thank you for your participation.

Appendix 3

Typical answers



الجامعة العربية الأمريكية
ARAB AMERICAN UNIVERSITY

The Impact of Educational Sessions on Mechanical Ventilator Waveforms' knowledge among Palestinian ICU Nurses: Quasi-experimental Study

Answers Sheet for Pre and Post Questionnaires:

Q1	C
Q2	B
Q3	B
Q4	A
Q5	C
Q6	A
Q7	B
Q8	A
Q9	C
Q10	C
Q11	C
Q12	D
Q13	C
Q14	D
Q15	B

Appendix 4

Invitation to attend the educational session.

Arab American University
Faculty of Graduate Studies



الجامعة العربية الأمريكية
كلية الدراسات العليا

حضرة الدكتور أحمد البيتاوي المحترم / المدير التنفيذي لمجمع فلسطين الطبي / رام الله.
بواسطة الأستاذة ابتسام شقور / مدير التمريض في مجمع فلسطين الطبي.

تحية طيبة وبعد،،،

الموضوع: دعوة لحضور ورشة عمل بخصوص التنفس الاصطناعي

مهديكم الجامعة العربية الأمريكية أسى آيات الترحيب والشكر لتعاونكم الدائم معنا، وتدعوا كافة ممرضي وممرضات العناية المكثفة في مجمع فلسطين الطبي لحضور ورشة عمل بخصوص اليات التعامل مع أجهزة التنفس الاصطناعي لمرضى العناية المكثفة وذلك يوم السبت الموافق 2023/5/27 الساعة 10:00 صباحا في حرم الجامعة العربية الأمريكية في رام الله / المسرح- طابق سالب 1. وعليه، ستقوم الدكتورة دينا أبو جبر بإعطاء المحاضرة نظريا وعمليا بالمشاركة مع شركة صندوقة للمعدات الطبية. راجين من حضرتكم تسهيل حضور ومشاركة ممرضي أقسام العناية المكثفة.

وتفضلوا بقبول فائق الاحترام والتقدير،

د. عماد أبو خضبر

مساعد عميد الدراسات العليا للشؤون الطبية



Appendix 5

Permission e-mail to use the study questionnaire.



Rawan Saadi <rawan.sa92@gmail.com>

Permission for a questionnaire

Rawan Saadi <rawan.sa92@gmail.com>

Thu, 6 Oct 2022 at 0:23

To: <adh.botha@gmail.com>

Cc: Imad Rasheed Ali Abu Khader <Imad.Abukhader@aaup.edu>, <Nisreen.salama@aaup.edu>

Respected Dr. ADH Botha,

My name is Rawan Ali Saadi, I'm a master's degree student in critical care nursing at Arab American University- Palestine. I have read the thesis you supervised "An educational programme for critical care nurses on the interpretation of ventilator graphics" By Sonja Windsor with great interest. I am currently working on similar topic "The impact of educational sessions on Ventilator waveforms knowledge among Palestinian ICU nurses."

Would you consider sharing your research tool (questionnaire) with me? It appears to be potentially very useful to my research and I would be eternally grateful.

If you have further questions, do not hesitate to contact me. I am eagerly awaiting your reply.

Thank you and many regards,

Rawan

Appendix 6

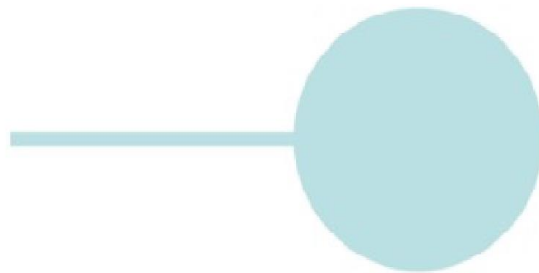
Mechanical Ventilator basic lecture material by Dr. Dina Abujaber:

Mechanical ventilator Basic

Dr. Dina Abu Jaber
M.D.MRCP(UK),EDIC

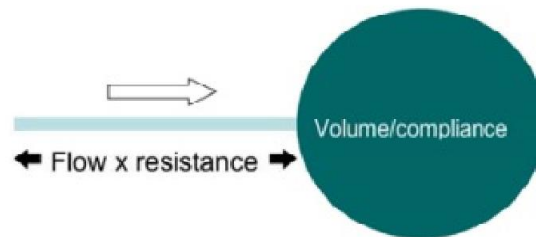
1

Physics



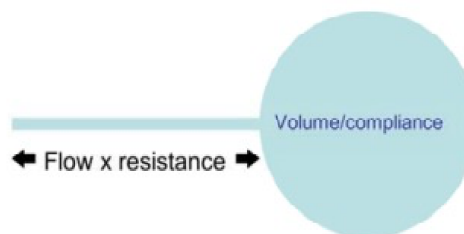
2

Physics



3

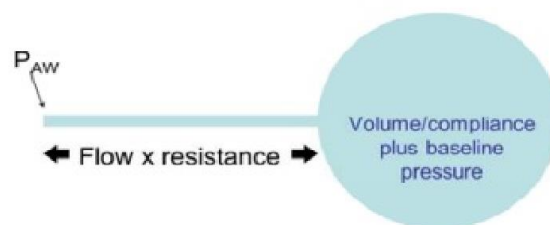
Physics



$$\text{Inflation pressure} = \text{Flow} \times \text{Resistance} + \frac{\text{Volume}}{\text{Compliance}}$$

4

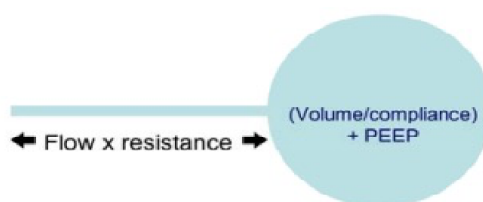
Physics



$$P_{AW} = \text{Flow} \times \text{Resistance} + \frac{\text{Volume}}{\text{Compliance}} + \text{Baseline pressure}$$

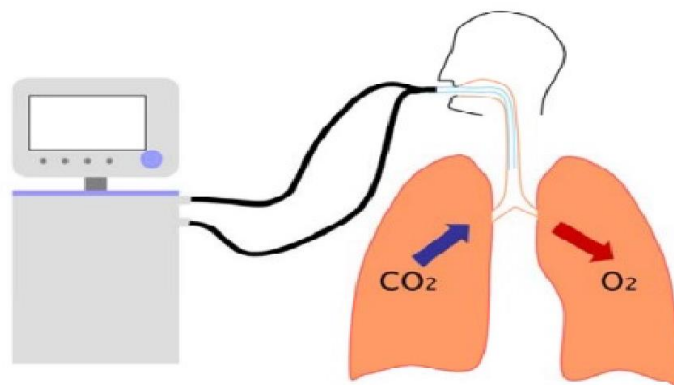
5

Physics

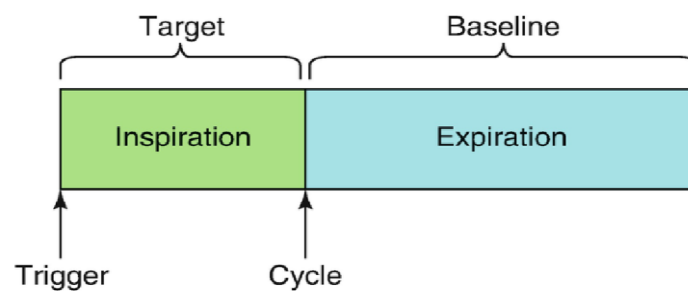


$$P_{alv} = \frac{\text{Volume}}{\text{Compliance}} + PEEP$$

6



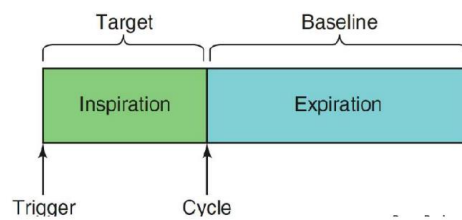
7



8

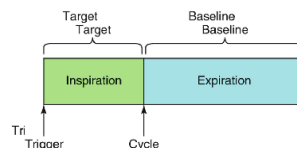
“Anatomy of a Breath”

- trigger → when inspiration begins
- target → how flow is delivered during inspiration
- cycle → when inspiration ends
- baseline → proximal airway pressure during expiration



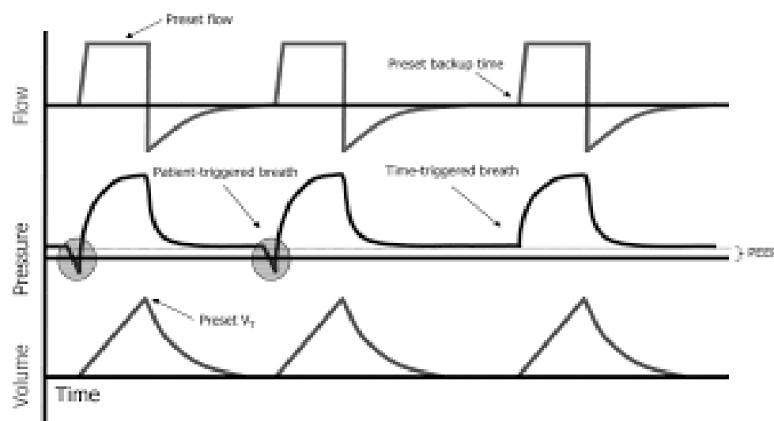
9

Trigger



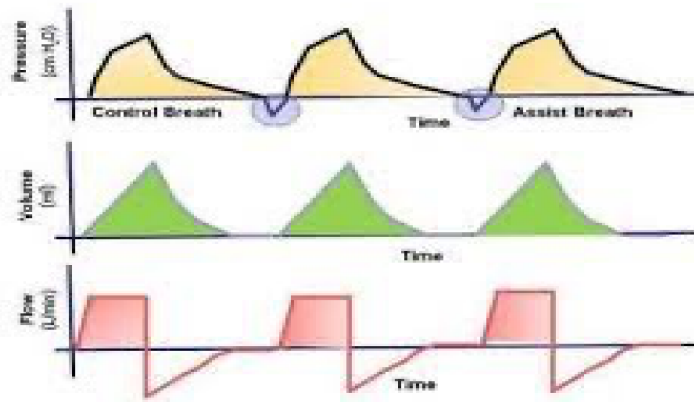
- **Determines who initiate the breath**
 - ventilator
 - Patient
- **Ventilator Trigger**
 - Controlled breath
 - Variable that set is Time (Breath / min)
 - if RR 12 the ventilator will deliver one breath every 5 seconds
- **Patient Trigger**
 - Assist
 - Flow or Pressure changes sensed by ventilator

10

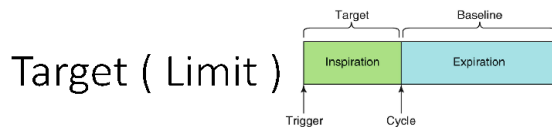


11

**Assisted Mode
(Volume-Targeted Ventilation)**



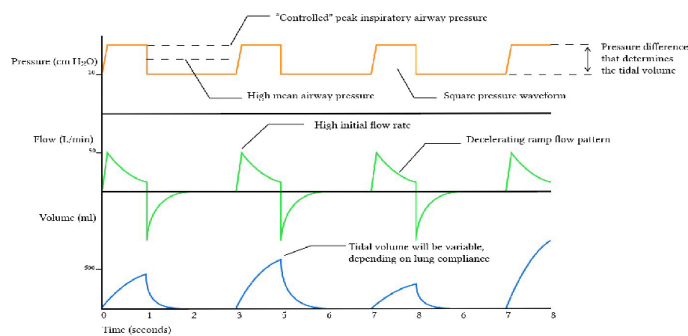
12



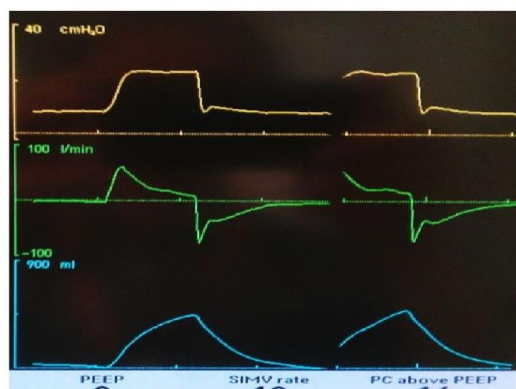
- Target is the variable you want to sustain and not to exceed during inspiration
- Pressure Target
- Flow Target

13

Pressure Target (Pressure Control Ventilation)



14



15

- Pressure control Setting
 - PC
 - Ti
 - RR
 - The pressure wave will be constant

16

Advantage of Pressure Target(Pressure Control)

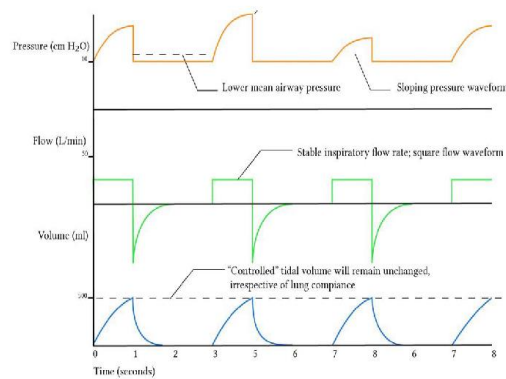
- **Increased mean airway pressure**, which improves oxygenation
- **Increased duration of alveolar recruitment**: with a square pressure waveform, alveoli are opened earlier and remain open for longer, allowing better gas exchange
- **Pressure limited ventilation may protect against barotrauma**

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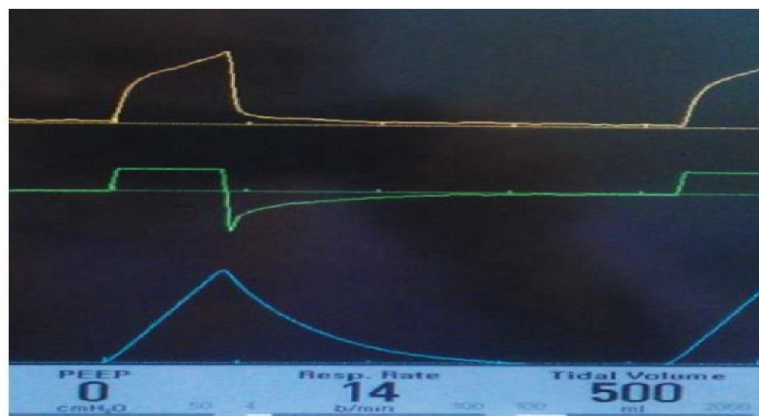
Disadvantages of PCV

- Tidal volume is dependent on respiratory compliance
- Uncontrolled volume may result in volutrauma
- A high early inspiratory flow may breach the pressure limit

Flow Targeted (Volume control)



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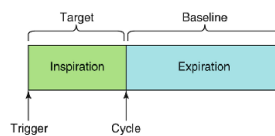
Advantages of volume control ventilation

- **Guaranteed tidal volumes produce a more stable minute volume.**
- **The minute volume remains stable over a range of changing pulmonary characteristics.**
- **The initial flow rate is lower than in pressure-controlled modes.**

Disadvantages of volume control ventilation

- **The mean airway pressure is lower**
- **Recruitment may be poorer in lung units with poor compliance.**
- **In the presence of a leak, the mean airway pressure may be unstable.**
- **Insufficient flow may give rise to patient-ventilator dyssynchrony.**

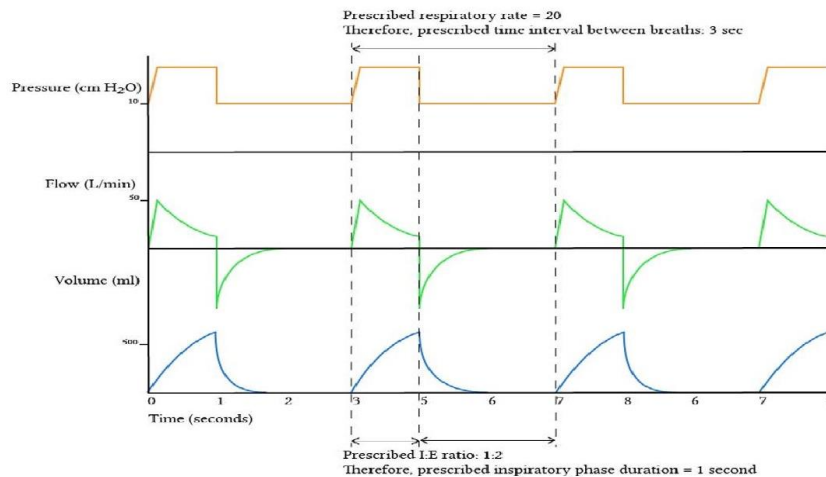
Cycle



- How the inspiration ends
 - Time Cycled
 - Flow Cycled
 - Pressure Cycled
 - Volume Cycled

Time Cycled

- if the inspiratory phase ends when a predetermined time has elapsed.
- This is usually a feature of controlled modes of ventilation (sedated Patient)
- For example , when one has set a respiratory rate of 20 and an I:E ratio of 1:2, it is understood that the inspiratory phase will last 1 second in a total 3-second breath cycle. After 1 second the ventilator will terminate inspiratory flow and cycle to expiration.



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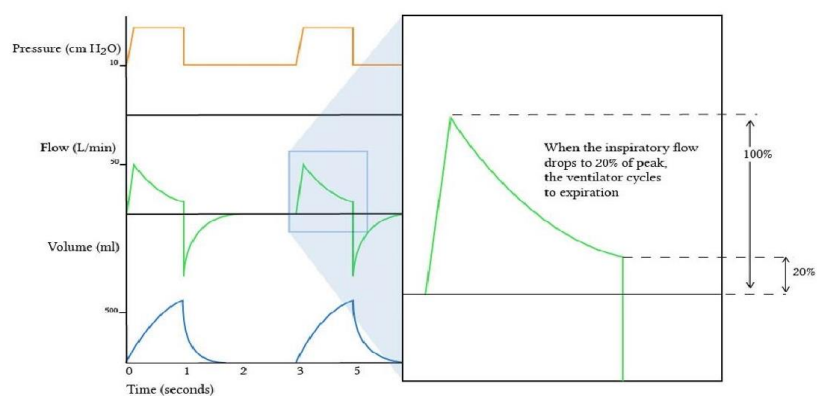
The advantages of time cycling

- A careful control of minute volume can be achieved
 - Ventilation is unaffected by changes in lung compliance or airway resistance
 - Minute ventilation is not affected by an unreliable respiratory drive
- ☐ Disadvantages
- It is unsuitable for lightly sedated and awake patients, .
 - It may result in patient-ventilator dyssynchrony

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Flow-cycled ventilation

The ventilator cycles into the expiratory phase once the flow has decreased to a predetermined value during inspiration.



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Pressure-cycled ventilation

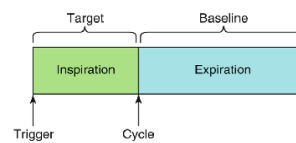
- inspiration ends when a certain user-prescribed pressure value is achieved.

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Volume targeted

- The inspiratory phase of a volume-cycled breath ends when the specified volume has been delivered.

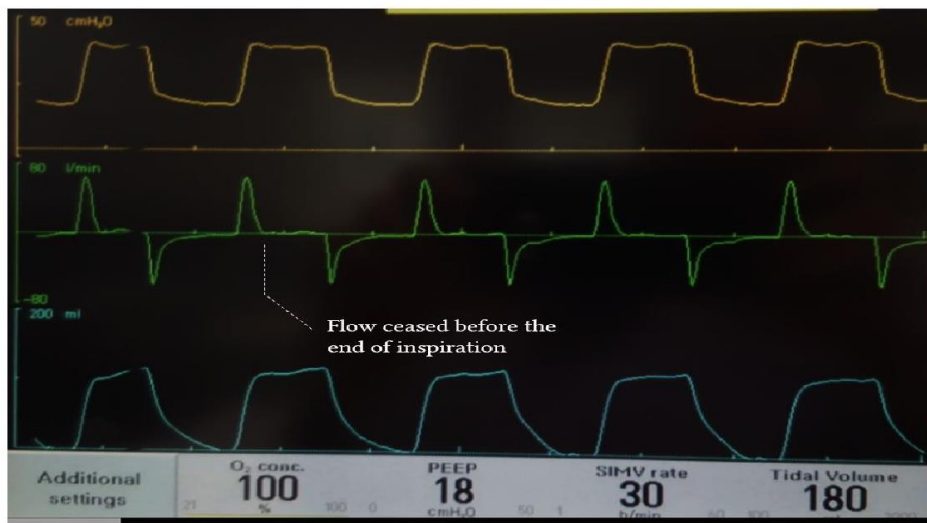
Baseline



- Airway pressure during expiration
- Passive process depend on lung recoil and chest wall
- It should reach zero line before next breath

Ventilator Waveforms

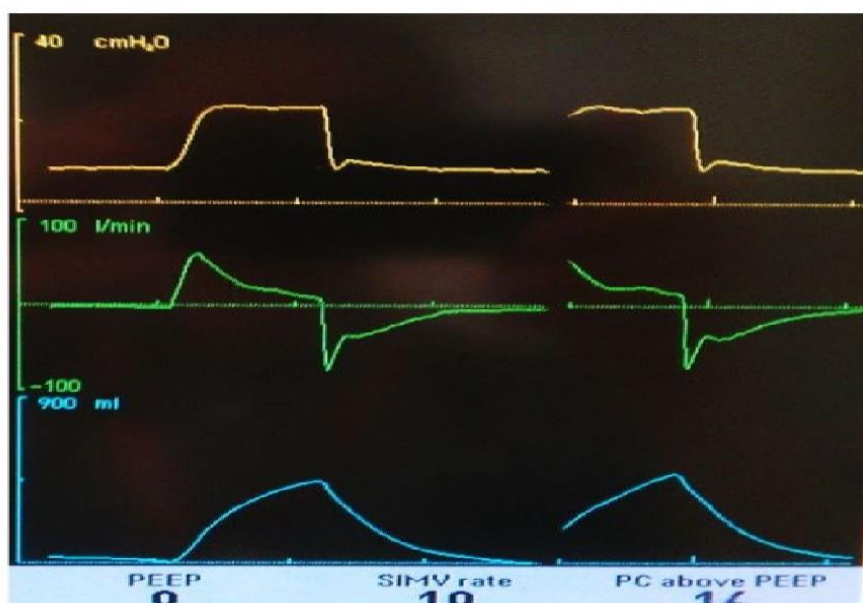
- Ventilator waveforms are graphical descriptions of how a breath is delivered to a patient.
- Three scalars (flow versus time, volume versus time, and pressure versus time)
- Two loops (pressure-volume and flow-volume).

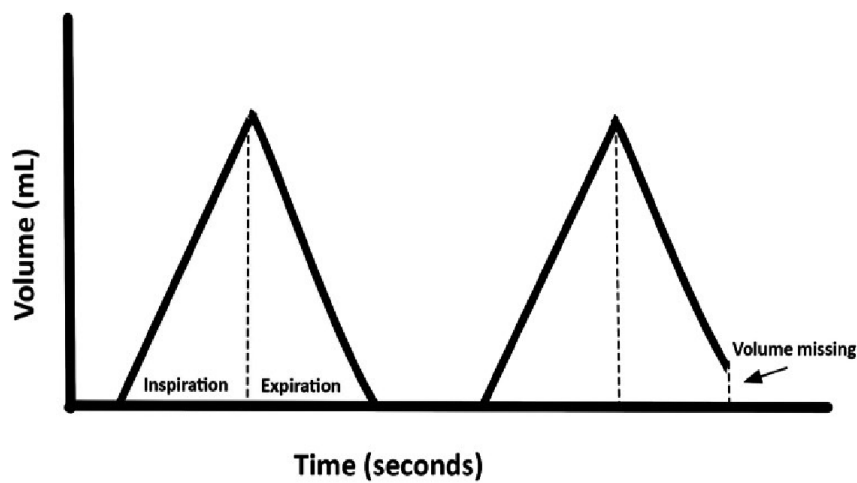


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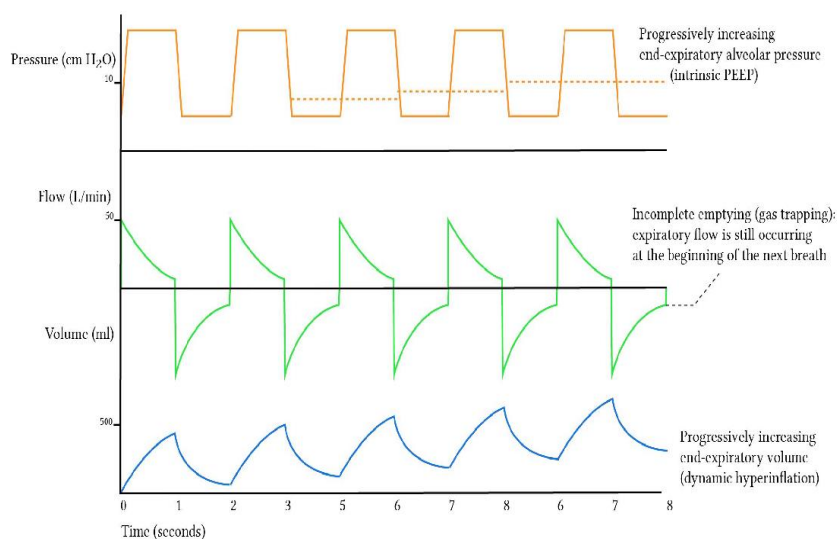
Volume Versus Time Scalar

- The volume versus time scalar is the graphical representation of the amount of gas delivered into the lungs by the ventilator over time.
- The upslope is the inspiratory volume and the downslope is the expiratory volume
- Inspiratory and expiratory volumes should be similar, and differences can indicate air leaks in the system or intrinsic positive end-expiratory pressure (i.e. auto-PEEP or air trapping)





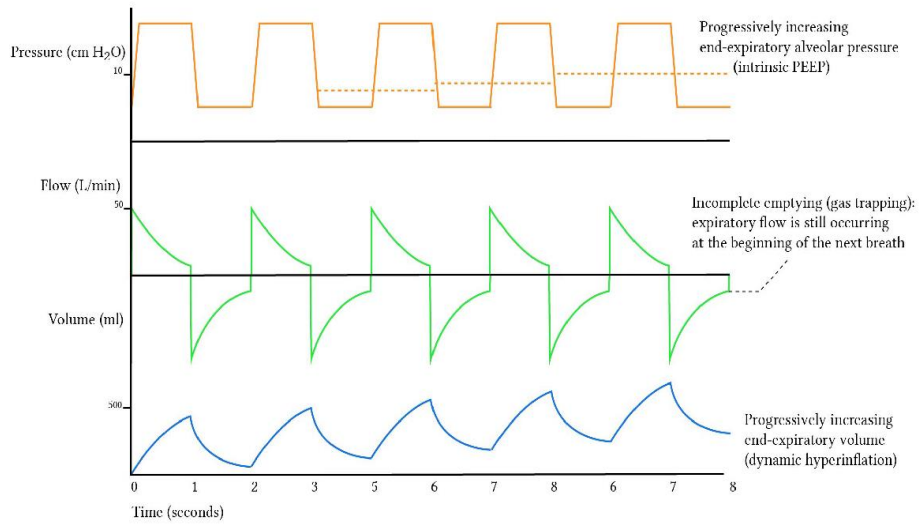
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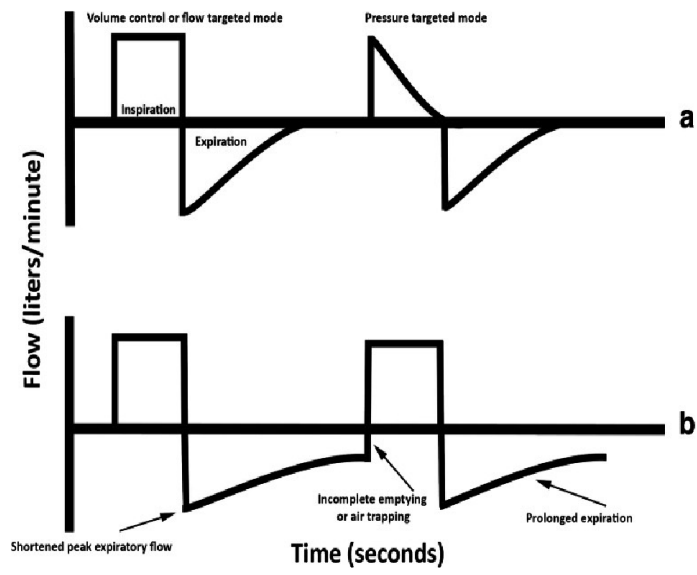
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Flow Versus Time Scalar

- Gas flow in between the patient and the ventilator is represented by the flow versus time scalar.
- Inspiratory flow is a positive value on the graph, whereas expiratory flow is a negative value. The area under the curve represents the volume moved during the phases of breathing



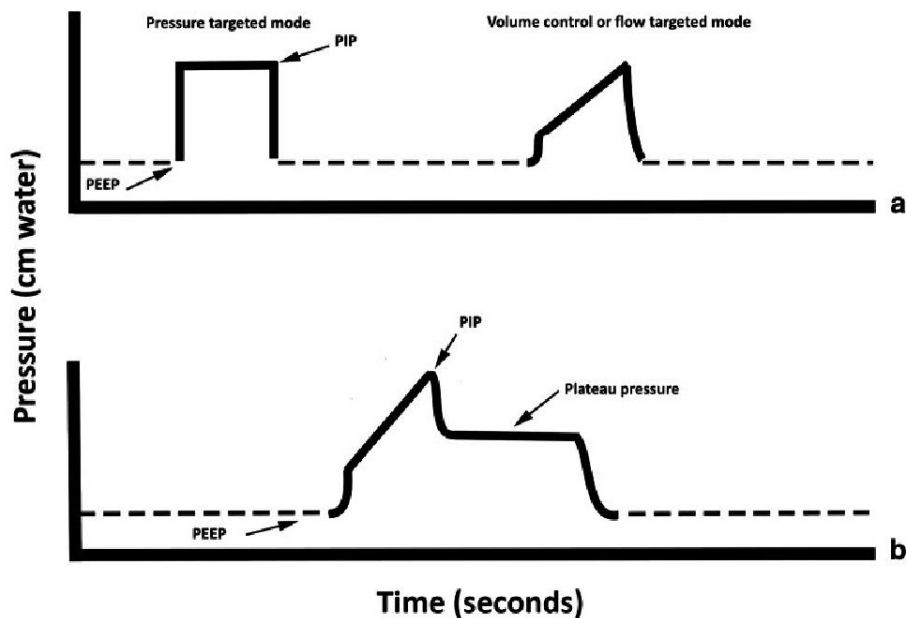
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Pressure Versus Time Scalar

- provides a good information about airway compliance to the clinician
- This can be a fixed or variable amount depending on the mode of ventilation
- During pressure control ventilation, the pressure delivered is constant and the pressure scalar is square-shaped
- In volume control ventilation, the pressure scalar is ascending due to the rise in pressure with a constant flow pattern



Patient-ventilator dyssynchrony

- Dyssynchrony is the effect of the patients respiratory demands not being appropriately met by the ventilator. The patient has their own idea about how to breathe, and the machinery supporting them, instead of making breathing easier, interferes with respiration and increases the work of breathing.

- **The work of breathing increases**
- **The oxygen demand increases**
- **The patient becomes distressed**
- **The patient begins to cough and/or vomit**
- **It increases ICP and decreases CPP-**
- **It increases the length of ventilation and ICU stay.**

Types of dys-synchrony

- Trigger
- Target
- Cycling

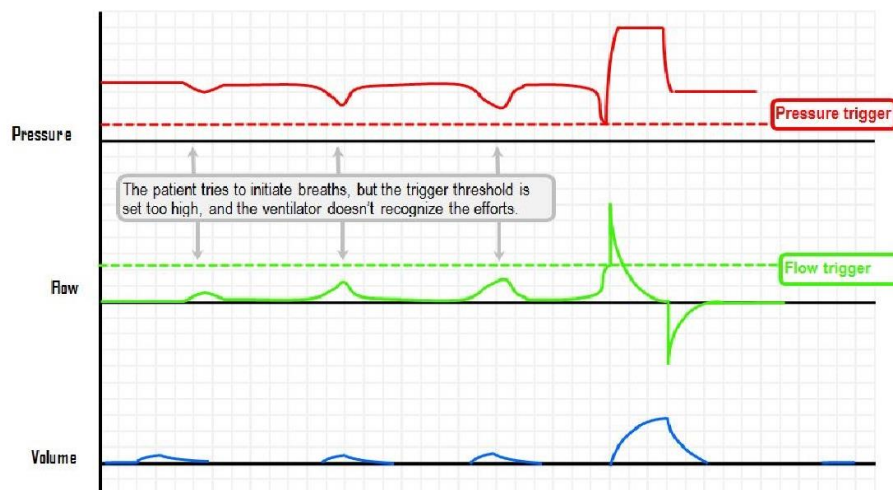
Dys-synchronies Related to Breath Initiation

- This occurs when the ventilator fails to respond to a patient's effort to take a breath
- There are several types of trigger asynchronies including
 - ineffective triggering leading to delayed or missed breaths
 - double triggering
 - auto-triggering

Trigger dys-synchrony

- Ineffective triggering
 - Pt tries to initiate breath however ventilator does not deliver a breath
- Extra Triggering
 - Ventilator deliver breath in absent of patient efforts

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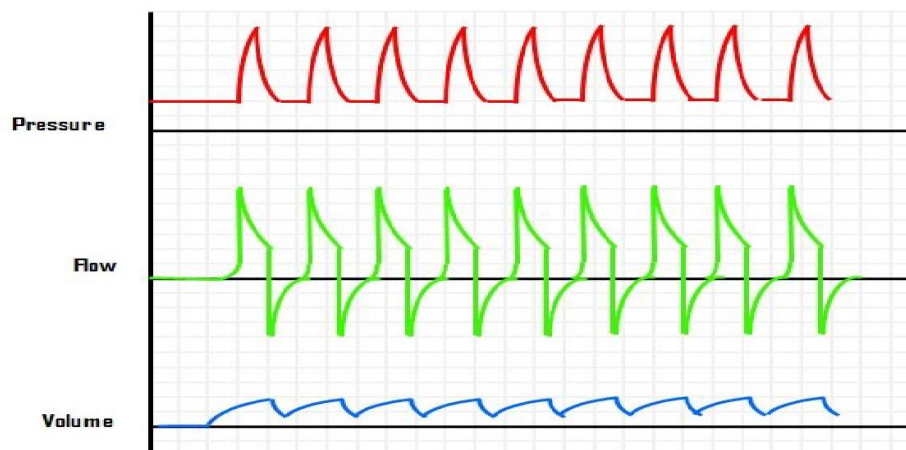
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Ineffective triggering

- Pt tries to initiate breath ,however ventilator does not deliver a breath
- **Causes**
 - Too high flow or pressure trigger
 - Diaphragmatic weakness
 - Air trapping

Extra Triggering

- Ventilator deliver breath in absence of patient efforts
- Auto-triggering: the trigger is too sensitive. Non-respiratory factors trigger the ventilator.



Causes of auto triggering

- Cardiac oscillations
- Leak from the circuit
- Leak from the chest drain (eg. a bronchopleural fistula)
- Inappropriate sensitivity settings
- Water condensation sloshing and bubbling in the circuit
- Large volume of respiratory secretions, eg. bronchiectasis
- Swallowing or vomiting
- Peristalsis in a massive hiatus hernia or intrathoracic bowel loops
- Muscle contractions due to external pacing (or misplaced leads in transvenous pacing)
- Transmitted movement from patient transport or repositioning
- IABP (Turns out, the balloon can generate enough gas displacement to fool a flow trigger.

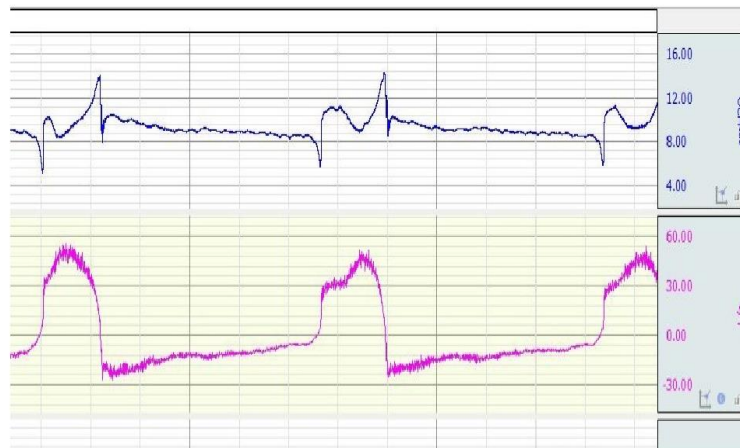
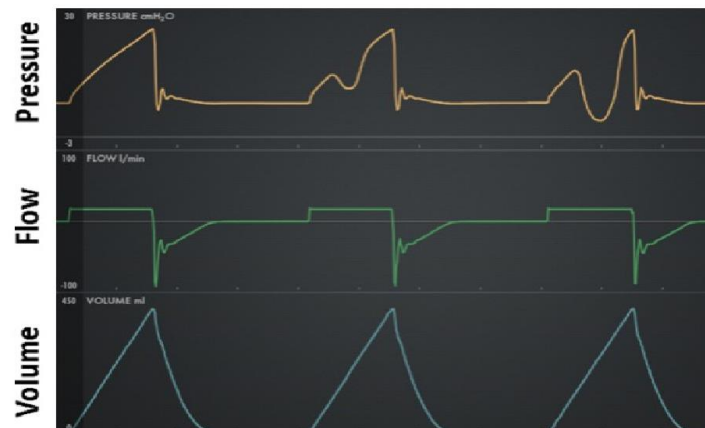
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Target dys-synchrony

- Issue on how the breath is delivered particularly due to flow problem
- Flow starvation (the flow the patient is receiving is not enough)
- It happen usually in volume control as it is flow dependent

- Flow rate is inadequate to meet inspiratory flow demand
- In order to breathe comfortably, one needs a steady flow of gas, at a sufficiently high rate.
If the flow demand is not met, the patient makes an effort ON TOP of the ventilator effort.
This appears as a "scalloping" of the pressure-time curve, which reflects the fact that the patient is generating a negative pressure with their respiratory muscles while the ventilator turbine is generating a positive pressure.

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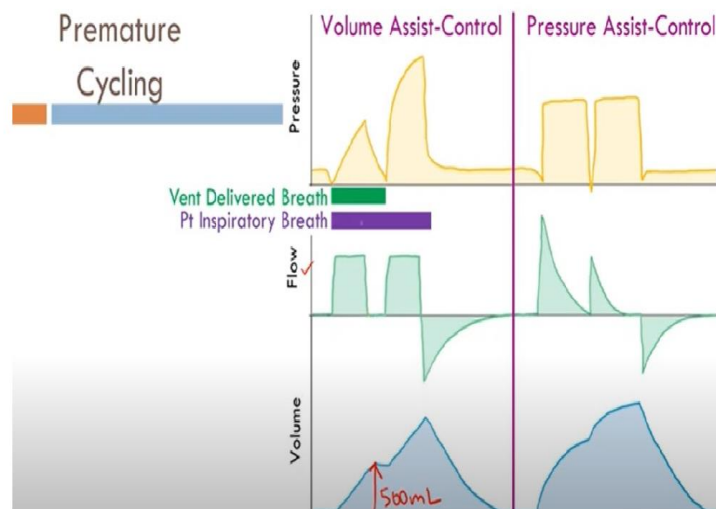


Cycle dys-synchrony

- Dys-synchrony in terminating the breath
 - Premature cycling
 - Delayed Cycling
 - Inspiratory time issue

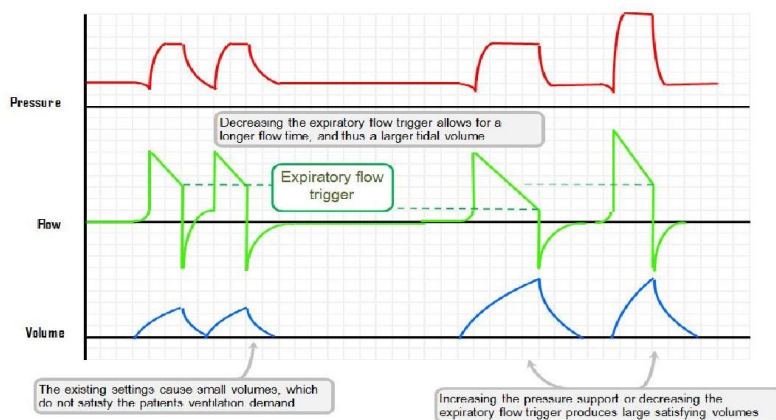
Premature cycling

- Patient continues to have inspiratory effort after ventilator has cycled off inspiration
- Two breath will be delivered with no exhalation



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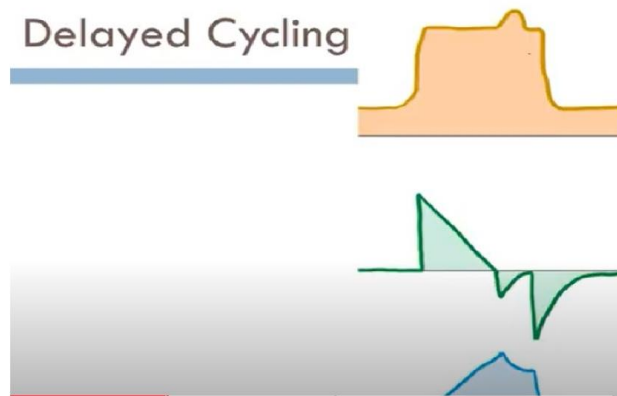
Double triggering and premature breath termination



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Delayed Cycling

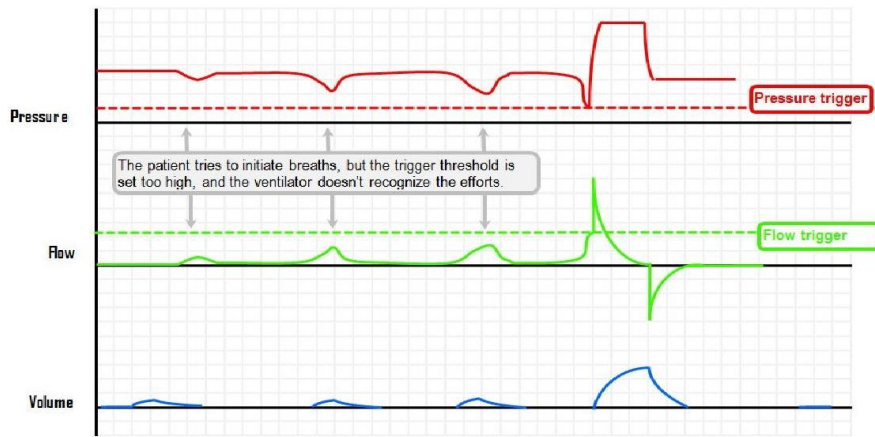
- Patient initiate expiration while ventilator in inspiratory phase
- Seen as positive notch inflection on inspiratory phase (Pressure scale)



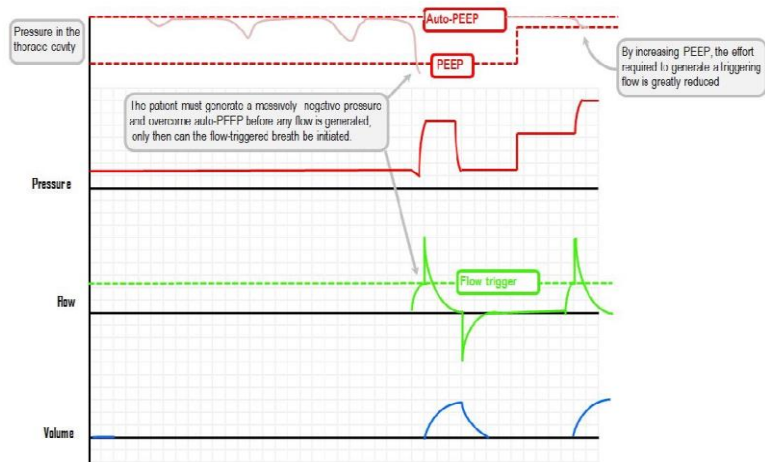
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الملخص

المقدمة: تتضمن موجات أجهزة التهوية معرفة حاسمة للتهوية الميكانيكية الآمنة والناجحة. في ظروف الرعاية الحرجة، يمكن للممارسين الصحيين المتخصصين تفسير هذه الموجات بدقة، مما يمكنهم من إجراء التعديلات اللازمة وتقديم العلاجات في الوقت المناسب وتحسين نتائج المرضى. هدفت هذه الدراسة إلى التحقق من مستوى المعرفة لدى مرضي وحدات العناية المركزة الفلسطينيين حول موجات التهوية الميكانيكية وتأثير جلسات التعليم عليها.

المنهجية: استخدم الباحث تصميمًا كميًا شبه تجريبيًا قبل وبعد مع مجموعة واحدة على عينة مريحة من 72 ممرضًا في وحدات العناية المركزة في الضفة الغربية - فلسطين. تلقى الممرضون جلسة تعليمية متعلقة بموجات التهوية الميكانيكية من متخصص، وأجابوا على استبيان قبل وبعد الجلسة. تم تحليل البيانات باستخدام برنامج SPSS، حيث استخدمت مقاييس ملخصة (مثل التكرارات والمتوسط والانحراف المعياري، ... الخ) لوصف البيانات وتم تنفيذ اختبارات استنتاجية (مثل اختبار t، اختبار Chi-square، تحليل التباين الأحادي الاتجاه، ... الخ) للتحقق من العلاقات والاختلافات بين المتغيرات الدراسية. تم جمع البيانات بطريقة مجهولة وسرية.

النتائج: الرئيسية أظهرت أن 50٪ من الممرضين كانوا ذكورًا، وكان متوسط أعمارهم 28.44 ± 4.75 سنة، وكان لديهم خبرة في التمريض ووحدات العناية المركزة لمدة 6.34 ± 4.33 و 4.66 ± 3.63 سنوات على التوالي. كان متوسط درجة المعرفة قبل الاختبار يساوي 43.704 ± 16.67 ٪، وكان ذلك مرتبطًا بشكل كبير بعمر الممرضين الأكبر وخبرة وحدة العناية المركزة الأعلى (قيمة $p = 0.019$ و 0.004 على التوالي). زادت الدرجة بشكل كبير إلى متوسط درجة ما بعد الاختبار والتي بلغت 67.315 ± 16.53 ٪، وكان ذلك أيضًا مرتبطًا بشكل كبير بعمر الممرضين الأكبر وخبرة وحدة العناية المركزة الأعلى (قيمة $p = 0.039$ و 0.004 على التوالي)، حيث لم يكن زيادة الدرجة مرتبطة بشكل كبير بأي من العوامل الديموغرافية أو المهنية.

الختام: هناك تأثير إيجابي لجلسات التعليم على معرفة موجات التهوية الميكانيكية بين الممرضين الفلسطينيين. هناك حاجة لإجراء مزيد من الدراسات لتقييم التأثير على مدى فترات زمنية متعددة بعد جلسات التعليم، بالإضافة إلى المقارنة بين التخصصات المختلفة. يجب أن تستمر جهود التعليم المستمر داخل المؤسسات الصحية في فلسطين.

ب.

الكلمات المفتاحية: Mechanical Ventilator, Waveforms, Graphics, Educational Sessions,

Asynchrony