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Knowledge and Practice of Intensive Care Nurses Towards Weaning Criteria From Mechanical Ventilation at Public Hospitals in Sana'a City-Yemen

Thesis Submitted to the Department of Applied Medical Sciences, College of Medical Sciences, AL-Razi University as Partial Fulfillment for MSc. in Critical Care Nursing

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جـامــــعـة الرازي
الدراسات العليا
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قسم العلوم الطبية التطبيقية

معارف وممارسات ممرضي العناية المركزة تجاه معايير الفطام من جهاز التنفس الاصطناعي في المستشفيات العامة بمدينة صنعاء- اليمن

رسالة مقدمة إلى قسم العلوم الطبية التطبيقية، كلية العلوم الطبية ،جامعة الرازي لاستكمال متطلبات نيل درجة الماجستير في تمريض الحالات الحرجة

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DECLARATION

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for and other degree or qualification.

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CERTIFICATE

This is to certify that the thesis entitled ***Knowledge and practice of intensive care nurses towards weaning criteria from mechanical ventilation at public hospitals in Sana'a City-Yemen***; which submitted to the Department of Applied medical sciences, College of Medical Sciences, Al-Razi University for the award MSc. degree in ***Critical Care Nursing***. It is a recorded of the original and bona fide thesis work carried out by ***Abdullateef Ahmed Mohammed Fere Al-Gunaid*** under our guidance. Such material as has been obtained from other sources has been duly acknowledged in the research. This thesis embodies the work of the candidate herself and no part thereof has been submitted for any other degree.

Supervisor

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DEDICATION

This thesis is dedicated to

My great parents, who never stop giving of themselves in countless ways, My dearest wife, who leads me through the valley of darkness with the light of hope and support,

My beloved brothers and sister,

My beloved kid: Neena whom I cannot force myself to stop loving. To all my family, the symbol of love and giving, My friends who encourage and support me, All the people in my life who touch my heart.

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LIST OF ABBREVIATION

AACCN	American Association of Critical Care Nurse
ATC	Automatic tube compensation
ACCP	American college of chest physicians
ABG	Arterial blood gazes
ARDS	Acute respiratory distress syndrome
BAL	Broncho-alveolar lavage
BiPAP	Bi-level positive airway pressure
bpm	Breath per minute
APRV	Airway pressure release ventilation
BSCs	Bachelor of science
CACM	Combination (assist & control mode)
CaO_2	Arterial oxygen content in vol%
CCN	Critical care nursing
CcO_2	End-capillary oxygen content in vol%
CvO_2	Mixed venous oxygen content in vol%
CPAP	Continuous positive pressure airway pressure mode
C_{ST}	Static lung compliance in mL/cm H_2O
ARDS	Acute respiratory distress syndrome
C-ICU	Cardiac – intensive care unit
CM	Controlled mode
cmH_2O	Pressure measured in cm of water
CNS	Central nervous system
COPD	Chronic obstructive pulmonary disease
CO_2	Carbon dioxide
C°	Centigrade
DRG	Dorsal respiratory group
E-ICU	Emergency – intensive care unit
VE	expired volume
$PetCO_2$	End-tidal partial pressure of carbon dioxide
ETT	Endotracheal tube
ECMO	Extracorporeal membrane oxygenation
HFOV	High-frequency oscillation ventilation
F	Frequency
FIO_2	Fractional inspired oxygen
G-ICU	General – intensive care unit
H	Hour
HAP	Hospital-acquired infection
HCWs	Health care workers
HCAP	Health care-associated pneumonia
HOB	Head of bed
H+	Hydrogen ions
H2	Histamine
ICU	Intensive care unit
I:E	Inspiration to expiration
IRV	Inverse ratio ventilation

PpI	Inspiratory plateau pressure
IPPB	Intermittent positive pressure breathing
PCVVG	Pressure control ventilation-volume guarantee
Kg	Kilogram
L	Liter
LTV	Long-Term Ventilation Weaning
VCV	Volume control ventilation.
M-ICU	Medical – intensive care unit
mcg	Microgram
Mg	Milligram
MIP	maximum inspiratory pressure
ML	Milliliters
mm Hg	Millimeter mercury
MMV	Mandatory minute ventilation
M_V	Minute Ventilation
MV	Mechanical ventilation
ACMV	Assists control ventilation
MV	Mechanical ventilation
N	Numbers
NAVA	Neutrally adjusted ventilator assists
NIPPV	NON- invasive positive pressure breathing
NIV	NON- invasive ventilation
NIF	Negative inspiratory force
O_2	Oxygen
OC	Oxygenation Criteria
PaO_2	Partial pressure of arterial oxygen
$PaCO_2$	Partial pressure of carbon dioxide in arterial blood
$P_{(A-a)}O_2$	Alveolar-arterial oxygen tension gradient
P_AO_2	Alveolar oxygen tension in mmHg
PaO_2/FIO_2	Arterial Oxygen Tension to Inspired Oxygen Concentration Index
PaO2	Arterial oxygen tension in mmHg
PC	Pressure control
PEEP	Positive end expiratory pressure
P_ECO_2	Mixed expired carbon dioxide tension in mmHg
P-ICU	Pediatric – intensive care unit
Blood PH	The acidity or alkalinity of the blood
RF	Respiratory failure RF
PRVC	Pressure regulated volume control
PS	Pressure support
RR	Respiratory rate
RSBI	Rapid shallow breathing index
PTC	Protected telescoping catheter
PBW	Predicted body weight
Q	Questions
QS/QT	Shunt percent in %
RR	Respiratory rate
SaO_2	Saturation of hemoglobin
sec	Second

SBT	Spontaneous breathing trial
SCCM	Society of critical Care Medicine
SF	Spontaneous Frequency
STV	Spontaneous tidal volume
SD	Standard division
SIVM	Spontaneous invasive ventilation modes
S-ICU	Surgical – intensive care unit
SIMV	Synchronized intermittent mandatory ventilation
SP	Spontaneous mode
SPSS	Statistical package for the social science
PM	Pressure mode
US	United State
USD	United State dollars
VAC	Ventilator – associated condition
VAP	Ventilator associated pneumonia
VAPS	Volume-assured pressure support
VAT	Ventilator- associated trachea bronchitis
VC	Vital Capacity
VAV	Volume-assisted cycles VAV
VBS	Ventilator bundles strategies
VC	Volume control
V_D/V_T	Deadspace to tidal volume ratio in %
ΔV	Corrected tidal volume in mL
ΔP	Pressure change (PPLAT - PEEP) in cm H2O
VRG	Ventral respiratory group
VT	Tidal volume
VS	Volume support
VTE	Ventilator event
WBC	White blood cell
WC	Weaning criteria
WOB	Work of breathing
WFSTV	Weaning from short-term ventilation
WFLTV	Weaning from long-term ventilation
WCFMV	Weaning criteria from mechanical ventilation
ZEEP	Zero end expiratory pressure
µL	Microliters

ABSTRACT

Background of the study

Weaning from M is the process of gradually withdrawing artificial ventilation to the intubated patients for short or long time in critical care setting.

Objective of the study

The objective of the study was to assessment the knowledge and practices of ICU nurses regarding the weaning criteria from the ventilator in public hospitals in Sana'a – Yemen

Research Methodology

A descriptive cross-sectional study was carried out at a public hospitals in Sana’a City-Yemen among ICU nurses. The sample size was 93 Yemeni nurses. The sample size was determined through used EpiCalc 2000. A stratified simple random sampling was applied. Data were collected by using a close-ended questionnaire to testing knowledge and observational checklist to testing nurses practice. A pilot study was conducted and validity and reliability of the questionnaire was also tested. The data were analyzed using SPSS and measured using frequency and percent for categorical variables and Means and SD for quantitative variable. t-test was used to determine the differences between two variables and one-way ANOVA determine the differences between more than two variables. χ^{2-} test was used to determine the relationship between categorical variables. A P-value <0.05 was considered statistically significant. Approval from Al-Razi University was obtained and principles of hospitals and oral consent was obtained from nurses to participate in the study.

Results

The results showed that (51.6%) of ICU nurses were male, (52.7%) were married with mean ± SD, 29.7 ± 4.5 years old, (75.3%) had working experience from 1-5 years. Two third (64.5%) of them had a diploma degree, (40.9%) had courses training in ICU and (83.9%) of them had not received training program on the WC ftom MV. (54%) of the nurses had correct knowledge toward WC from MV whereas (46%) of them had incorrect knowledge. While (39%) of nurses had poor knowledge, and (50%) of them had moderate knowledge and (11%) of them had good knowledge, While (46%) of the nurses were correctly practiced to WC from MV, whereas (44%) of them were not done and (10%) need correctly practiced. As regards to level of practice, (49%) had poor practice, (36%) had a moderate practice and (15%) had a good practice. There was no significant differences in the mean knowledge scores toward WC by demographic characteristics of nurses (P>0.05).

A significant differences in the mean knowledge scores toward WC according to diploma degree in respiratory therapy was found (P<0.05) but not for course training in WC and courses training in ICU (P>0.05). A statistically significant differences was found in mean practice scores toward WC from MV by demographic characteristics of

nurses (P<0.05) but not for sex (P>0.05). A statistically significant differences was found in mean practice scores toward WC from MV by diploma degree in respiratory therapy, course training in WC and courses training in ICU (P< 0.05).

Conclusion and Recommendations

This study conclude that (50%) of the nurses had moderate knowledge toward WC from MV and (36%) of them had moderate practice, This study recommended increasing knowledge and practice of ICU nurses through the courses training and implementation WC and protocol weaning in all ICU units.

الخلاصة

خلفية الدراسة

الفطام من جهاز التنفس لاصطناعي هو عملية سحب من جهاز التنفس الاصطناعي تدريجيًا للمرضى الذين هم على جهاز التنفس الاصطناعي لفترة قصيرة أو طويلة في وضع الرعاية الحرجة.

هدف الدراسة

تهدف هذه الدراسة إلى تقييم معارف وممارسات ممرضي العناية المركزة تجاه معايير الفطام من جهاز التنفس الاصطناعي في المستشفيات العامة في صنعاء-اليمن.

المنهجية

دراسة وصفية مقطعية عرضية اجريت على ممرضي العناية المركزة في المستشفيات العامة بمدينة صنعاء-اليمن ، لتقييم معارف وممارسات ممرضي العناية المركزة تجاه معايير الفطام من جهاز التنفس الاصطناعي. شملت عينة الدراسة على ٩٣ ممرض وممرضة العاملين في وحدات العناية المركزة. تم تحديد حجم العينة من خلال استخدام EpiCalc 2000. وتم اخذ العينة باستخدام العينة العشوائية الطبقية. تم جمع البيانات عن طريق الاستبيان المكتوبة لتقيم المعارف والملاحظة لتقييم الممارسات. قام الباحث بأجراء اختبار قبلي لأداة جمع البيانات وكذا قام باختبار المصداقية والثبات للاستبيان قبل جمع البيانات. تم معالجه البيانات وتحليلها باستخدام برنامج الحزم الاحصائية للعلوم الانسانية النسخة ٢١ واستخدام التكرار والنسب للمتغيرات النوعية والمتوسط الحسابي والانحراف المعياري للمتغيرات الكمية. تم قياس الفروقات بين متغيرين باستخدام اختبار تي كذألك تم استخدام تحليل التباين الاحادي لقياس اكثر من متغيرين. تم قياس العلاقات بين المتغيرات باستخدام مربع كأي والفا كرومبخ لاختبار ثبات فقرات الاستبيان وتم مراعاة مستوى الدلالة عند $P < 0.05$. تم الحصول على الموافقات الرسمية المكتوبة من جامعة الرازي واماكن الدراسة المختارة، وكذلك تم اخذ الموافقة الشفوية من قبل الكادر التمريضي للمشاركة في الدراسة.

النتائج

أظهرت النتائج أن (٥١.٦٪) من ممرضات العناية المركزة كانوا من الذكور و(٥٢.٧٪) كانوا متزوجين بمتوسط ± ٢٩.٧ ± ٤. ٥ سنة ، (٧٥.٣٪) لديهم خبرة عمل من ١-٥ سنوات. (٦٤.٥٪) حاصلين على درجة الدبلوم ، (٤٠.٩٪) حاصلين على دورات تدريبية في وحدة العناية المركزة و (٨٣.٩٪) لم يكن لديهم برنامج تدريبي على معايير الفطام من جهاز التنفس الاصطناعي. اثبتت الدراسة أن (٥٤٪) من ممرضي وحدة العناية المركزة كانت لديهم معارف صحيحة تجاه الفطام من جهاز التنفس الاصطناعي و(٤٦ ٪) كانت لديهم إجابة خاطئة. اثبتت الدراسة ان (٣٩٪) من ممرضي وحدة العناية المركزة لديهم معرفة ضعيفة تجاه معايير الفطام من جهاز التنفس الاصطناعي و(٥٠٪) لديهم معرفة متوسطة في حين أن (١١٪) فقط كانت لديهم معرفة جيدة بالنسبة لمستوى الممارسات كان (٤٦٪) يمارسون بشكل صحيح كل الاجراءات المتعلقة بالفطام من جهاز التنفس الاصطناعي و(٤٤٪) لم يمارسون الاجراءات بينما (١٠٪) يحتاجون الى تصحيح ممارساتهم. بالنسبة لمستوى الممارسات كان (٤٩٪) من الممرضين لديهم مستوى ضعيف من الممارسات، بينما (٣٦٪) لديهم ممارسات متوسطة و (١٥٪) كانت لديهم مستوى جيد من الممارسات. لا يوجد فرق ذو دلاله في المتوسط الحسابي للمعارف بحسب البيانات الديمغرافية ($p<0.05$). هناك فرق ذو دلاله في المتوسط الحسابي للمعارف والحاصلين على دبلوم المعالجة التنفسية ($p<0.05$) بينما لا يوجد فرق ذو دلاله احصائية في المتوسط الحسابي للمعارف والدورات التدريبية في وحدة العناية المركزة و البرنامج التدريبي على معايير الفطام من جهاز التنفس الاصطناعي ($P>0.05$)عدا بحسب الجنس ($P >0.05$). أثبتت الدراسة ان هناك فرق ذو دلاله احصائية في المتوسط الحسابي للممارسات بحسب البيانات الديمغرافية ($p<0.05$). وهناك فرق ذو دلاله احصائية في المتوسط

الحسابي للممارسات والحاصلين على دبلوم المعالجة التنفسية والدورات التدريبية في وحدة العناية المركزة والبرنامج التدريبي على معايير الفطام من جهاز التنفس الاصطناعي ($p < 0.05$).

الاستنتاجات والتوصيات

استنتجت هذه الدراسة أن (٥٠٪) من ممرضي وحدة العناية المركزة كانت لديهم معرفة متوسطة تجاه معايير الفطام من جهاز التنفس الاصطناعي، كما كان نسبة (٤٩٪).من الكادر التمريضي مستوى ممارستهم متوسط. نوصي بزيادة المعارف والممارسات لممرضي وحدة العناية المركزة من خلال الدورات التدريبية وتطبيق برتوكولات الفطام في جميع المستشفيات.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Mechanical ventilation (MV) is applied to treat respiratory insufficiency caused by failure of oxygenation and respiratory muscles to improve gas exchange and reduce the work of breathing ***(Robert E. Hyatt et al, 2014)***. As soon as the clinical status is improving, the process of liberation from respiratory (weaning) can be initiated. In about 15–20% of patients the weaning process is significantly delayed. “Prolonged weaning” is defined by failure of at least 3 spontaneous breathing trials (SBT) or, if the process lasts more than 7 days, after the first SBT ***(Talwar, 2016).***

Advanced technology is a major part of the ICU and MV is one of the most commonly used treatment modalities in the care of the critically ill patient, Up to 90% of patients globally require MV during some or most part of their stay in the ICU ***(Frutos-vivar, 2017)***. The mechanical ventilation is a key component in the care of critically ill and injured patients. Delays in weaning patient from MV increases the number of complications and may lead to increased expenditure. Consequently, weaning constitutes a major challenge for the intensive care staff. It is important to wean the patient from MV as expeditiously as possible. Several studies indicate that the implementation of nurse-led, criteria weaning reduces the amount of time spent on MV, the length of ICU stay, and associated costs ***(Mamta Thapa, 2013)***

Mechanical ventilation is often life-saving procedures, but constitutes an expensive treatment modality which is associated with iatrogenic complications such as ventilator-associated pneumonia (VAP) and ventilator-induced lung injury, which can lead to the development of the acute respiratory distress syndrome (ARDS) and increased mortality and morbidity ***(Mcgrattan, 2013)***. The reasons for initiating MV are diverse. The most common reasons for initiation of MV are described as follows:

pneumonia/acute lung injury (33.2%), chronic obstructive pulmonary disease (9.7%), cardiogenic pulmonary oedema (5.2%) neurological emergencies (16.9%), post-operative complications (24%) and cardiopulmonary arrest (11%) ***(Garriga, 2016)***.

The time used versus time available for weaning ratio represents a new way of reporting the weaning status and process at an organizational level. Although various patient and systemic factors were linked to weaning activity, the most important factor was whether the intensive care unit nurse's made use of time available. It showed that weaning frequently was given low priority despite being an essential part of care of the mechanically ventilated patients. It is vital for intensive care nurses to deliver high quality care to the critically ill patient using relevant technologies but also incorporating psychosocial care measures. This balance is often one of the largest challenges facing by nurses in the intensive care environment. For this reason, intensive care nurses need to determine the unique interventions that will positively impact on the mechanically ventilated patient and assist in the patient's progression toward desired outcomes ***(Carter, 2012)***.

Critical care nurses' skill level is dependent upon their knowledge, experience of, and exposure to, critically ill patients ***(Mohammad, 2015)***. Nurses can improve patient recovery by skilled and timely reduction of sedation as well as weaning from ventilation. The skilled critical care nursing will reduce the risk of complications, the number of critical care bed days and improve patient outcomes. Nurses' is key provider of information to patients, relatives and other members of the interdisciplinary team ***(Markle, 2014)***.

The population with prolonged weaning is challenging since treatment of these patients requires great experience of invasive and non-invasive mechanical ventilation, adjunctive treatment strategies and intensive care medicine. Moreover, successful weaning often requires a joint multidisciplinary treatment approach (e.g. intensive care medicine, internal medicine, thoracic surgery, otolaryngology, phoniatry/speech therapy, physiotherapy, occupational therapy, pain management, psychiatry and neurology) ***(Nathan woody, 2013: Quraishi, 2016)***.

1.2 Problem Statement

About 20% to 30% of patients are difficult to wean from invasive mechanical ventilation. The pathophysiology of difficult weaning is complex. Accordingly, determining the reason for difficult weaning ***(Frutos-vivar, 2017)***, Weaning the patient from mechanical ventilation can be very challenging problems in the intensive care unit, especially in patients with underlying pulmonary disease and after prolonged ventilation periods ***(Bösel, 2017).***

Prolonged mechanical ventilation (MV) leads to high resource utilization and poor outcomes. Patients that require prolonged weaning experience longer hospital stays as well as increased complications, mortality and healthcare costs ***(Talwar, 2016; Cederwall, and Ringdal, 2018).*** If weaning is delayed, costs are increased, as are the risks of nosocomial pneumonia, cardiac-associated morbidity, and death. On the other hand, weaning too soon often results in reintubation, which is associated with complications similar to those of prolonged ventilation ***(Frutos-vivar, 2017).***

The cost of providing care to critically ill patients in the United States consumes roughly 15% of all health care dollars. Contributing to this economic burden are patients admitted to the intensive care unit (ICU) who require MV and patients with complications from their dependence on this technology. In fact, 50% of ICU patients receive MV (***willian Owens, 2018; Crocker, & Scholes, 2009).***

Prolonged MV for critically ill patients is associated with adverse clinical outcomes, including physiological and psychological experiences. Consequently, in an effort to reduce morbidity and mortality associated with MV, clinical and research attention, over the last 20 years, has been focused on reducing the duration of mechanical ventilation ***(Blackwood,B. et al 2014).*** Although most research has added greatly to our understanding of the weaning process, we continue to struggle with questions of how and when to wean ***(Kydonaki, 2011).***

Weaning practice requires that bedside nurses continually make decisions about the patients‟ ventilation management. The ability to make clinical judgments involves a complex process using both domain-specific knowledge and decision-making methods ***(Kydonaki, 2011).*** About 70% to 80% of patients who require MV for respiratory failure were extubated after a trial of spontaneous breathing trial once the precipitating process has been corrected. About 20% to 30% of patients who require intubation, however, do not tolerate initial attempts to breathe without the help of the ventilator ***(David M. 2017).***

Weaning from MV is the process of gradually withdrawing artificial ventilation to the intubated patients for short or long time in critical care setting. Weaning patients from ventilator is complex and challenging task for nurses, knowing and practice-weaning criteria are most essential to successful patient's outcome with MV***(Judith et al, 2016).***

1.3 Justification of the study

The Justification of this study was providing baseline information on assessment weaning criteria from MV. The nurse's team members playing very curial role in successful weaning process from MV and prevent re-intubation of patients. According to previous study conducted in Nepal by Bal Kumari reported that more than the half of the nurses had inadequate knowledge regarding weaning criteria (***Bal Kumari, 2017).***

Weaning from MV is a major issue in intensive care units (ICUs). The weaning process comprises at least 40% of the total duration of MV and prolonged MV is associated with significant morbidity and mortality. Therefore, minimizing the duration of MV is an important consideration for clinicians who care for critically ill patients, and weaning from MV should be considered as soon as possible. A recent meta-analysis revealed that in most trials, protocol-based weaning has been shown to reduce duration of MV, weaning, and ICU length of stay. However, approximately 15% of patients receiving MV require a prolonged process of weaning and experience higher mortality ***(Andrew et al, 2016)***

The findings of this study will help in planning a comprehensive teaching/training program to improve nursing care practices toward weaning criteria from MV and reduce complication rates that associated with weaning process. So on another hand this was improving the patient outcome. Improved patient outcomes will shorten the patient's length of stay in hospitalization as well as benefit the patient financially with decreased hospital costs ***(Hierro-majadahonda, 2017).***

Therefore, the objective of this study was to assess the knowledge and practice of ICU nurses toward weaning criteria from mechanical ventilation at public hospital in Sana'a City Yemen.

CHAPTER TOW: LITERATURE REVIEW

2.0 Introduction

This chapter begins with providing an insight about the theoretical part and empirical part that contain the anatomy and physiology of respiratory system, Pathophysiology of respiratory failure during weaning, respiratory failure and MV, classification modes MV and advance mode, Pathophysiology of respiratory failure during weaning, also weaning criteria from MV defined, criteria, method, types, readiness, intervention, evidence weaning, parameter, guideline long and short ventilation, protocol weaning, extubation.

2.1 Section One: Anatomy and Physiology of Respiratory System

2.1.1 Anatomy of the respiratory system

In humans and other mammals, the anatomy of a typical respiratory system is the respiratory tract. The tract is divided into an upper and a lower respiratory tract. The upper tract includes the nose, nasal cavities, sinuses, pharynx and the part of the larynx above the vocal folds. The lower tract, includes the lower part of the larynx, the trachea, bronchi, bronchioles and the alveoli ***(Heather et al, 2016)***. The branching airways of the lower tract are often described as the respiratory tree or tracheobronchial tree, The intervals between successive branch points along the various branches of "tree" are often referred to as branching "generations", of which there are, in the adult human about 23. The earlier generations (approximately generations 0–16), consisting of the trachea and the bronchi, as well as the larger bronchioles which simply act as air conduits, bringing air to the respiratory bronchioles, alveolar ducts and alveoli (approximately generations 17–23), where gas exchange takes place. Bronchioles are defined as the small airways lacking any cartilagenous support ***(Edward, 2017***; ***Gustavo et al, 2008).***

The first bronchi to branch from the trachea are the right and left main bronchi. Second only in diameter to the trachea (1.8 cm), these bronchi (1 -1.4 cm in diameter) enter the lungs at each hilum, where they branch into narrower secondary bronchi known as lobar bronchi, and these branch into narrower tertiary bronchi known as segmental bronchi. Further divisions of the segmental bronchi (1 to 6 mm in diameter) are known as 4th order, 5th order, and 6th order segmental bronchi, or grouped together as subsegmental bronchi ***(Jean-Louis, 2019; Nugent and Edriss, 2017).***

2.1.2 Physiology of respiratory system

The main function of the respiratory system is to carry out gas exchange, oxygen and carbon dioxide between human beings and their environment. Thus the respiratory system facilitates oxygenation and removal of carbon dioxide and other gases metabolism discarded. In the respiratory system we differentiate two stages: inspiration, breathing air, during this the diaphragm contracts and flattens in order to expand the chest cavity, and earn a vacuum to suck air into the lungs. The second stage is the exhalation, the diaphragm relaxes so that regains its shape expelling air from the lungs ***(Heather et al, 2016; Richard & Michael, 2006; Lumb, 2016)***.

The process of physiological respiration includes two major parts: external respiration and internal respiration. External respiration, also known as breathing, involves both bringing air into the lungs (inhalation) and releasing air to the atmosphere (exhalation). During internal respiration, oxygen and carbon dioxide are exchanged between the cells and blood vessels. Respiration begins at the nose or mouth, where oxygenated air is brought in before moving down the pharynx, larynx, and the trachea. The trachea branches into two bronchi, each leading into a lung. Each bronchus divides into smaller bronchi, and again into even smaller tubes called bronchioles. At the end of the bronchioles are air sacs called alveoli, and this is where gas exchange occurs An important structure of respiration is the diaphragm. When the diaphragm contracts, it flattens and the lungs expand, drawing air into the lungs. When it relaxes, air flows out, allowing the lungs to deflate ***(Linda, 2014)***.

2.1.3. Pathophysiology of respiratory failure during weaning

Weaning from MV depends on the strength of respiratory muscles, the load applied to those muscles, and the respiratory drive to breathe. Respiratory failure may occur because of any of these. For example, muscular dystrophy (weakness of respiratory muscles), acute bronchospasm (increased respiratory load), or narcotic overdose (reduced central drive) all may lead to respiratory failure. In general, the etiology of unsuccessful weaning is the imbalance between the respiratory muscle pump and the respiratory muscle load. This could happen secondary to inadequate resolution of the initial problem that rendered the patient on MV, a rise of a new problem, a ventilator-associated complication, or a combination of these factors ***(Robert, 2018; Peate & Karen, 2014).***

Respiratory failure occurs due to mainly either to lung failure resulting in hypoxaemia or pump failure resulting in alveolar hypoventilation and hypercapnia. Hypercapnic respiratory failure may be the result of mechanical defects, central nervous system depression, imbalance of energy demands and supplies and/or adaptation of central controllers ***(Nugent and Edriss, 2017).*** Hypercapnic respiratory failure may occur either acutely, insidiously or acutely upon chronic carbon dioxide retention. In all these conditions, pathophysiologically, the common denominator is reduced alveolar ventilation for a given carbon dioxide production. Acute hypercapnic respiratory failure is usually caused by defects in the central nervous system, impairment of neuromuscular transmission, mechanical defect of the ribcage and fatigue of the respiratory muscles ***(Janice et al, 2015).***

2.2 Section Two: Mechanical Ventilation

2.2.0 Introduction to mechanical ventilation

Today, mechanical ventilation is the principal therapy used to treat severe respiratory failure caused by a serious disease or injury of any of the six key parts of respiratory system (i.e. the lungs, chest wall, airway, respiratory center, respiratory nerves, and respiratory muscles). If applied appropriately, this therapy effectively assists, supports, or replaces compromised natural lung ventilation, artificially satisfying the vital demands of respiration. This gives the clinician valuable time to treat the underlying diseases and improve the general condition of the patient ***(Frutos-vivar, 2017; Chahoud, J, 2015).***

2.2.1 Operating principles

Mechanical ventilation can be realized with one of three principles: intermittent positive pressure ventilation (IPPV), intermittent negative pressure ventilation (INPV), and high- frequency ventilation (HFV) ***(Tommaso and Eddy, 2017; Aoyama 2017).***

2.2.1.1 Intermittent negative pressure ventilation (INPV)

With the INPV principle, the ventilated patient’s mouth and nose are open to the atmosphere so that gas can move in or out when alveolar pressure changes relative to atmospheric pressure. During inspiration, a negative pressure is applied to the surface of the chest wall, temporarily reducing the alveolar pressure. Fresh air is now sucked into the lungs. During expiration, the applied negative pressure is removed. The elastic recoil force temporarily generates a positive alveolar pressure, squeezing the stale gas out of the lungs. The driving pressure changes opposite to the way it does in IPPV ***(Sanjeev et al, 2015).***

- **Iron lung (Drinker Respirator Tank)**

An “iron lung” ventilator encloses the patient’s body except for the head and neck in a tank, and the air in it is evacuated to produce a negative pressure around the chest cage. This negative pressure surrounding the chest and underlying alveoli results in chest wall and alveolar expansion**.** The tidal volume delivered to the patient is directly related to the negative pressure gradient. For example, a more negative pressure applied to the chest wall will yield a larger tidal volume. Since negative pressure ventilation does not require tracheal intubation, this noninvasive method of ventilation has been used extensively and successfully to support chronic ventilatory failure ***(Yuan Lei, 2017; Lindahl, 2012).***

- **Chest cuirass (Tortoise Shell)**

The chest cuirass or chest shell is a form of negative pressure ventilation that was intended to alleviate the problems of patient access and tank shock associated with iron lungs. This shell device covers only the patient’s chest and leaves the arms and lower body exposed. Although the chest shell improves patient access and decreases the potential for tank shock, ventilation with this device may be limited by the difficulties in maintaining an airtight seal be- tween the shell and the patient’s chest wall ***(Jonathon et al, 2011)).***

2.2.1.2 Intermittent positive pressure ventilation (IPPV)

With the IPPV principle, the patient’s respiratory system is integrated into the ventilator system. A positive pressure is applied intermittently to the patient’s airway. When the airway pressure is temporarily higher than the alveolar pressure, fresh gas is pushed into the lungs, the process of inspiration. When the airway pressure is lower than alveolar pressure, the gas is expelled out of the lungs, the process of expiration. Both inspiration and expiration are regulated by the operator's settings. shows a typical pressure waveform in IPPV. IPPV is the common principle of most modern ventilators ***(Morton, 2013***; ***Gustavo et al., 2008).***

- **Pressure cycled ventilators**

have one advantage; leak compensation, provided it is a minor leak. The inspiration goes on till the set pressure is reached despite the leak. This will allow the volume, flow, and time that are sufficient to ventilate the patient ***(Jennifer and Buettner, 2010)***.

- **Volume-cycled ventilators**

The inspiratory phase of a volume-cycled breath is terminated when the preset volume has been delivered. In most cases, the volume remains constant even if the patient's lung characteristics change. The pressures required to deliver the preset volume and gas flow, however, will vary as the patient's respiratory system compliance and airway resistance change ***(Wang, et al, 2015)***.

- **Flow-Cycled Ventilation**

With flow-cycled ventilation, the ventilator cycles into the expiratory phase once the flow has decreased to a predetermined value during inspiration. Volume, pressure, and time vary according to changes in lung characteristics. Flow cycling is the most common cycling mechanism in the pressure-support mode, flow termination occurs when the flow reaches a percentage of the peak inspiratory flow ***(Irwin et al, 2014).***

- **Time-Cycled Ventilation**

A breath is considered time cycled if the inspiratory phase ends when a predetermined time has elapsed. The interval is controlled by a timing mechanism in the ventilator, which is not affected by the patients's respiratory system compliance or airway resistance. At the specified time, the exhalation valve opens (unless an inspiratory pause has been used) and exhaled air is vented through the exhalation valve. If a constant gas flow is used and the interval is fixed, a tidal volume can be predicted, Tidal volume = Flow (Volume /Time) ×Inspiratory time ***(Carter, 2012).***

2.2.1.3 High frequency ventilation (HFV)

Both IPPV and INPV are regarded as 'conventional', because the tidal volume and respiratory rate are similar to physiological ones the third principle of mechanical ventilation is high- frequency ventilation. HFV uses a much higher respiratory rate (150 b/ min or higher) than we see with the other types. The tidal volume is much smaller than the physiological range, often smaller than dead space. The mechanisms of gas transport and exchange in HFV are very different from IPPV and INPV, and are not well understood ***(Blackwood, B, et al 2014; Kollef, et al, 2010)***.

2.2.2 Indications for mechanical ventilation

For hypoxemic and hypercapnic, respiratory failure, hypoxemic respiratory failure is divided into processes that require short-term and long-term ventilator support. hypercapnic respiratory failure is broken down into unstable ventilatory drive, muscle fatigue, excessive work of breathing, and alveolar hypoventilation neurologic and neuromuscular, congenital abnormalities (congenital diaphragmatic hernia congenital heart disease), chronic obstructive pulmonary disease (COPD) after major surgery to maintain oxygenation. Cardiogenic or septic shock to decrease myocardial workload and maintain oxygenation, Severe asthma/anaphylaxis, Acute respiratory distress syndrome (ARDS), Pneumonia, Burns and smoke inhalation and pulmonary disease ***(Cederwall, and Ringdal, 2018).***

2.2.3 Modes of ventilator support

Common modes of MV, Traditional modes of invasive mechanical ventilation use volume, pressure, flow and time to cycle from the inspiratory to the expiratory phase and can be administered as full or partial ventilator support. Full support provides the patient with adequate ventilatory requirements to meet metabolic demands without supplementation by the patient. Partial support provides partial ventilator assistance but requires patients to actively participate in their own spontaneous ventilation ***(Jean-Michel, 2018).***

The vast majority of patients in the ICU are managed using one of four modes of mechanical ventilation. These modes are either volume preset or pressure preset. In the volume-preset mode the clinician sets the rate and tidal volume and the ventilator delivers whatever pressure is required to achieve it. In the pressure- preset mode the clinician sets the maximal inspiratory pressure and inspiratory time, the ventilator delivers whatever tidal volume is generated by that pressure. Both pressure- and volume- presets ventilation can provide full ventilatory support. Volume preset ventilation assures minute ventilation that is set for the patients, even if lung mechanics change. Pressure preset ventilation purports to minimize ventilator induced lung injury, but changes in respiratory resistances or compliance may lead to significant decreases in ventilation ***(Marcel, 2011)***.

No specific considerations related to mode are recommended for pleural effusions with both volume-cycled and pressure-cycled modes likely to be effective after being appropriately adjusted for the volume and pressure issues mentioned. For the uncommon pleural disease of bronchopleural fistulas, high frequency jet ventilation is a mode that is commonly considered to be advantageous ***(Kathryn et al, 2017).***

Table 1: Mechanical ventilator mode categories *(Kathryn et al, 2017)*			
Category	Control	Support	Unassisted
Mode	VC, PC, PRVC	VS, PS, SIMV, BiPAP	CPAP, SB

2.2.3.1 Volume Preset Modes

Volume modes of ventilation deliver a fixed volume of gas into the lungs. The tidal volume and the respiratory rate are therefore set on the ventilator. It is often adopted for patients with normal compliant lungs undergoing surgery when a simple mode of ventilation is required. However, as this volume of gas is delivered into the patient regardless of the pressure in the patient's airway, monitoring of the patient's airway pressure is important to minimize the risk of barotrauma. There are two main volume modes, volume control ventilation (VCV) synchronized intermittent mandatory ventilation (SIMV) ***(Andrew et al, 2016)***

- **Assists control ventilation (ACV)**

In assists control mode, the operator is also allowed to control the percentage time that a patient spends during inspiration (Ti) while the VT is being delivered. The time a patient spends in expiration (Te) is a passive process that is driven by the elastic recoil of the lung and chest wall, and therefore beyond the control of the operator. The relationship of Ti to Te is typically referred to as the I:E ratio. The mechanism by which an operator controls Ti in AC mode is through control of the inspiratory flow rate (e.g., increasing inspiratory flow rate will decrease Ti). An operator should also be aware that inspiratory airway pressures are likely to change with adjustments to inspiratory flow as a result of airway resistance. Further discussion regarding appropriate selection of I:E ratios for specific respiratory conditions***(Sharon-Ann Shunker, 2016).***

- **Volume control ventilation (VCV)**

Volume control ventilation is a mandatory type of ventilation where a fixed volume for inspiration is delivered. In volume-targeted ventilation, the VT remains constant for each breath delivered by the ventilator. The VT is preset and is delivered by the ventilator until the preset volume is reached. In this mode the ventilator performs all of the WOB, without the patient initiating any effort, The minute volume is entirely delivered by the ventilator, respiratory rate, This mode is useful when the patient is experiencing apnea, for example, if the patient is suffering from a neurological condition or a drug overdose. Another reason to initiate volume-targeted ventilation is to fully rest the patient's diaphragm and respiratory muscles to allow healing of the underlying respiratory condition. To promote patient comfort, the sensitivity dial is set at –1 to –2 cm to permit the patient to trigger a ventilator breath with little effort ***(Robert* & Kenneth *2017***; ***Linda, 2014).***

- **Synchronized intermittent mandatory ventilation (SIMV**)

SIMV-VC is a mandatory mode of ventilation where the ventilator synchronizes delivery of the fixed volume of inspiratory breath to any spontaneous breathing effort the patient may make. SIMV-VC is often combined with pressure support to augment the patient's independent breaths The SIMV mandatory breaths may be either time-triggered or patient-triggered. The triggering mechanism is determined by whether or not the patient makes a spontaneous inspiratory effort just prior to the delivery of a time-triggered breath. For example, if the SIMV mandatory frequency is set at 10/min, then the ventilator would time-trigger a breath every 6 sec if the patient is not attempting to inspire spontaneously ***(Talwar, 2016; Sanjeev et al, 2015).***

2.2.3.2 Pressure mode (PM)

In pressure modes of ventilation, the ventilator delivers a flow of air to the lung until the pressure generated in the ventilator circuit reaches the pressure limit set on the ventilator. The benefit of this mode is lung protection, as it prevents the alveoli being over distended (volutrauma) and reduces the risk of excessively high pressures and rupture of the alveoli (barotrauma). Pressure modes of ventilation are mostly commonly used in patients who have stiff lungs, i.e. poor lung compliance such as in acute lung injury or ARDS. There are three main pressure modes, pressure control ventilation (PCV), bi-level ventilation, bi-level airway pressure release ventilation (APRV) ***(Frutos-vivar, 2017: Karen, 2016).***

- **Pressure control ventilation (PCV)**

Pressure control ventilation is a mode of ventilation where a pressure limit is set for each breath delivered by the ventilator. When this pressure limit is reached, the ventilator then cycles into an expiratory breath. The pressure in the patient's airway therefore determines the volume of each breath. This mode has a fixed breath rate. Patients on this mode are often heavily sedated and may also be receiving muscle relaxants to enable control of their respiratory function. It is important to monitor the size of the breath (tidal volume) as this was determined by the compliance of the patient's lungs. If the tidal volume is inadequate to maintain adequate patient gas exchange it may be necessary to increase the pressure limit on the ventilator***(Nugent and Edriss, 2017).***

- **Bi-level positive airway pressure (BiPAP)**

Bi-level ventilation is a specific mode of pressure control ventilation where a high and a low pressure are set on the ventilator and the machine cycles between the two. The patient can breathe in and out at nearly any point in the respiratory cycle and these breaths was pressure supported by the ventilator. During inspiration the breath is supported by pressure to the predetermined upper limit. At expiration the predetermined lower pressure is kept in the ventilator circuit and respiratory tract in order to keep the alveoli open. In this way ventilation and gas exchange is improved. The benefits of bi-level ventilation are that patient can receive a pressure-controlled mode of ventilation without requiring heavy sedation. This mode is comfortable for the patient as bi-level offers pressure control ventilation while allowing the patient to take their own breaths ***(Paul,et al, 2017; Helen Schaar, 2013).***

- **Bi-level airway pressure release ventilation (APRV) ventilation – also known as BiPAP APRV**

Bi-level APRV is a type of ventilation whereby the ventilator pressure rapidly decreases at the end of an inspiratory phase. The normal inspiratory I/expiratory (E) ratio is 1:2. However, in bi-level APRV the ventilator is set to an inverse inspiratory/expiratory ratio mode delivering a breath with a longer inspiratory phase with comparatively short expiratory time ***(Chang, D. W 2013).*** The aim of this mode of ventilation is to allow the lung to remain inflated for a longer period of time to promote the diffusion of oxygen across the alveoli/capillary membrane. The longer period of inspiration may increase the diffusion of oxygen but it reduces the time for CO_2 to be moved out of the lungs during the expiratory phase. For this reason this mode should only be used where PaO_2 levels are excessively low and permissive hypercapnia (low tidal volumes leading to raised CO_2 levels) is acceptable in order to promote patient oxygenation. Close monitoring of arterial blood gases is vital to ensure that the patient's CO_2 levels do not compromise the patient's acid-base (***Shinobu, 2012; Robert M., 2018).***

2.2.3.3 Hybrid invasive ventilation modes(HIVM) (Combination modes)

Over the past decade, ventilators have been developed that combine both pressure and volume modes of ventilation. Such modes have the advantage of delivering the maximum tidal volume in a breath at a lower predetermined airway pressure than if the patient was being ventilated on a volume mode of ventilation. This maximizes gas exchange while minimizing the risk of barotrauma. The main types of hybrid ventilation to date are. pressure control ventilation-volume guarantee (PCVVG) synchronized intermittent mandatory ventilation pressure controlled (SIMV-PC), neutrally adjusted ventilatory assist (NAVA) ***(Saiphoklang, N et al., 2018; Albert, J. et al, 2014).***

- **Pressure control ventilation-volume guarantee (PCV-VG)**

Pressure control ventilation-volume guarantee ventilation is a mode of ventilation where the inspiratory pressure limit is fixed and the volume of inspiratory breath is controlled.The ventilator attempts to ensure the patient receives the set volume within the set pressure limits. However, this mode does not provide any ventilator support to any spontaneous breathing. It is not therefore comfortable if the patient is waking and attempting to initiate their own breaths ***(Yuan Lei, et al, 2017; Linda, 2014)***.

- **Pressure Regulated Volume Control (PRVC).**

Volume control (PRVC) attempts to maintain a minimal target tidal volume with a constant pressure by manipulating the flow waveform. The ventilator initially performs a test breath sequence, which measures dynamic or static system compliance. Subsequent adjustments in pressure or tidal volume are made on the basis of the previous breath or a historical average of breaths. Some ventilators initiate a “test breath” sequence during PRVC by implementing a brief inspiratory pause during a volume-controlled breath. The static pressure measured during the pause was the pressure control level for the next breath. The following breaths will increase or decrease the pressure control level to try to achieve the set tidal volume with the lowest possible pressure ***(Brian, 2015; Sengupta et al, 2018).***

- **Synchronized intermittent mandatory ventilation–pressure controlled (SIMV-PC)**

Synchronized intermittent mandatory ventilation pressure controlled is a mandatory mode of ventilation but one where the ventilator synchronizes itself to any spontaneous breathing of the patient. This mode of ventilation is therefore often combined with pressure support ***(Mamta, 2013).***

- **Neurally adjusted ventilatory assist (NAVA)**

During weaning from mechanical ventilation, the overall aim is to reduce the number and degree of mechanically assisted breaths while increasing patient breaths until liberation from ventilator support is achieved. Providing 'too much' support will delay weaning, while providing 'too little' support will simply fatigue the patient Although clinical examination and measurement of vital signs during weaning are important, there is current and growing interest in more objectively and continuously measuring the degree of patient effort, and providing the 'right'amount of assistance on a breath-by-breath basis**.** Neurally adjusted ventilatory assist is a method of attempting to quantify and optimize the amount of ventilator support required as the patient's condition changes. Assessing respiratory effort may be by detection of neurological activity (e.g. in the respiratory centre, vague nerve، or diaphragm) or by measurement of lung mechanics and patient effort. Typically, more mechanical support is provided when patients can make only limited respiratory efforts, and the ventilator provides incrementally less support as the patient becomes stronger ***(Haugdahl, 2016 ; Moerer, 2019).***

2.2.3.4 Novel invasive ventilation modes

- **High-frequency oscillation ventilation (HFOV)**

HFOV typically uses special ventilators with a respiratory rate of 150–900 breaths/min, each delivering a small tidal volume. This tidal volume (typically less than 100 mL) is much lower than a patient's physiological dead space (typically150 – 200 mL), so oxygenation does not occur by direct delivery to the alveoli as with conventional ventilation. Instead, a complex number of factors, Including bulk flow and diffusion of oxygen from the trachea, account for the ability of HFOV to deliver sufficient oxygen to alveoli, the postulated benefits of HFOV include lower peak, but higher mean, intrathoracic pressures than conventional ventilation. This may permit more rapid healing of bronchopleural fistulae, or facilitate management of patients with severe ARDS by allowing ventilation without derecruitment ***(Kacmarek et al, 2017).***

- **Extracorporeal membrane oxygenation (ECMO)**

Conventional or high-frequency ventilation modes require that a patient has at least a minimum of functioning lung tissue to allow gas exchange. In very severe, but reversible، disease, ECMO may be an appropriate means to provide organ support until the lungs recover. A large double-lumen cannula is placed in the venous system (usually superior vena cava, although a variety of ECMO configurations exist). This drains deoxygenated blood، pumps it through a membrane oxygenator and then returns oxygenated blood to the patient via the second lumen. The patient's heart then pumps this oxygenated blood around the body. During this time, the lungs may be almost completely rested, and a variable degree of cardiac output can be provided by the ECMO pump ***(Tommaso and Eddy, 2017; Haugdahl, 2016; Patroniti,et al 2011).***

- **Spontaneous invasive ventilation modes (SIVM)**

Spontaneous modes of ventilation are when the patient is intubated and instigates the breath, and the ventilator assists the breathing with added pressure or flow. There are two main spontaneous modes of ventilation, Continuous positive pressure airway pressure mode (CPAP), Pressure support (PS) uses the same principles as BiPAP in non-invasive ventilation ***(Rosenthal, V. D, 2016).***

2.2.3.5 Advanced Modes of Mechanical Ventilation

With each generation of ventilators, new modes and variations on previous modes become available. There now exist numerous ventilator modes from a variety of manufacturers. The purpose of this chapter is to describe the technical and clinical aspects of advanced modes of ventilation that have recently become available. Although heavily promoted by their manufacturers, the clinical role of many of these modes remains unproven. Use of these modes is often based upon their availability and clinician's bias, rather than evidence that they are superior to traditional modes ***(Contro, 2019: Guilhermino et al, 2015).***

- **Dual-Control Modes**

With dual-control modes, the ventilator can automatically switch between pressure control and volume control during a single breath. However, it is important to remember that the ventilator is controlling only pressure or volume at any given time, not both at the same time. The proposed advantage of this mode is a reduced work-of-breathing (WOB) while maintaining a minimum minute volume and tidal volume (VT). This approach operates during mandatory breaths or pressure-supported breaths to combine the high initial flow of a pressure controlled breath with the constant volume delivery of a volume controlled breath. Names for this approach are volume-assured pressure support, pressure augmentation, and machine volume. These modes are not commonly available on the newest generation of ICU ventilators ***(Lamouret, 2019).***

- **Adaptive Pressure Control (APC)**

Adaptive pressure control is closed-loop PCV. Tidal volume is a feedback control for breath-by-breath adjustment of pressure control, All breaths are patient or ventilator-triggered, pressure-controlled, and time-cycled. This mode is available on most current ICU ventilators and has various names, dependent on the manufacturer, such as AutoFlow, pressure-regulated volume control (PRCV), volume control + (VC+), adaptive pressure ventilation, volume-targeted pressure control, and pressure controlled volume guarantee. The ventilator delivers a test breath and calculates system compliance. A number of breaths are delivered to test the pressure control necessary to achieve the desired tidal volume based on the compliance calculation. The ventilator then increases or decreases the pressure on a breath-by-breath basis to deliver the desired VT ***(Dres and Demoule, 2018; Guilhermino et al, 2015).***

Perhaps the most important advantage of this mode is the ability of the ventilator to change inspiratory flow to meet patient's demand while maintaining a constant minute volume, An important disadvantage of this mode is that the tidal volume remains constant and peak alveolar pressure increases as the lungs become less compliant (eg, acute respiratory distress syndrome), which could result in alveolar over distention and acute lung injury. With this mode, breaths can exceed set tidal volume in the presence of strong inspiratory efforts by the patient. When this occurs, the ventilator may excessively reduce the level of support, leading to asynchrony. On some ventilators a low-pressure limit as well as a high-pressure limit can be set ***(Edward, 2017).***

- **Volume Support (VS)**

Volume support (VS) is closed loop control of pressure support ventilation (PSV). Tidal volume is used as feedback control to adjust the pressure support level. All breaths are patient-triggered, pressure-limited, and flow-cycled. A test breath with a low-pressure is applied. The delivered tidal volume (exiting the ventilator) is measured and compliance is calculated. A number of breaths are then delivered to test the calculated pressure to deliver the set tidal volume. The ventilator then attempts to maintain a constant delivered tidal volume on a breath-to-breath manner. Since VS is a variation on PSV, the breath is flow-cycled There are several potential issues with this mode. Auto-positive end-expiratory pressure (auto-PEEP) may occur if the pressure level increases in an attempt to maintain tidal volume in a patient with airflow obstruction ***(David, J. Baker 2016).***

- **AutoMode**

Auto Mode allows the ventilator to switch between mandatory and spontaneous breathing modes. If the patient is apneic, the ventilator will provide VCV, PCV, or PRVC. If the patient triggers a breath, the ventilator switches from VCV to VS, from PCV to PSV, or from PRVC to VS. If the patient becomes apneic, the ventilator reverts to VCV, PCV, or PRVC ***(Bal Kumari, 2017; Michard, F., 2005)***

- **Average Volume-Assured Pressure Support**

Average volume-assured pressure support (AVAPS) is a form of adaptive pressure control available on some ventilators for noninvasive ventilation. It maintains a V T equal to or greater than the target VT by automatically controlling the minimum and maximum inspiratory positive airway pressure (IPAP) setting. AVAPS averages V T over time and gradually changes the IPAP over several minutes to achieve the target V T' If the patient's effort decreases, IPAP is increased to maintain the target tidal volume. On the other hand, if the patient's effort increases, IPAP i s reduced. As with other types of adaptive pressure control, there is a concern that the ventilator will inappropriately decrease support if respiratory drive increases ***(Hugh et al, 2015).***

- **SmartCare/PS**

SmartCare/PS is a mode that adjusts the level of PSV based on the patient's VT respiratory rate, end-tidal PCO_2, and preset parameters based on the patient's condition. SmartCare adjusts the PSV to maintain a normal range of ventilation (called the zone of comfort), defined as VT > 300 mL, a respiratory rate 12 to 30 breaths/min, and end-tidal PCO_2 < 55 mm Hg (assuming the patient weighs > 55 kg, without chronic obstructive pulmonary disease (COPD) or neurologic injury) . If the patient's ventilation falls outside of these parameters, SmartCare manipulates the PSV as often as every 5 minutes based on the current value, the clinician input parameters, and the patient's historical breathing pattern. SmartCare was designed to automatically wean patients from the ventilator. When the patient is weaned to PSV low enough, a spontaneous breathing trial is performed automatically. If the spontaneous breathing trial (SBT) is successful, the ventilator prompts the clinician to consider extubation ***(Chockalingam, T, 2015).***

- **Adaptive Support Ventilation**

Adaptive support ventilation (ASV) is based on the minimal WOB concept, which suggests that the patient will breathe at a tidal volume and respiratory frequency that minimizes the elastic and resistive loads while maintaining oxygenation and acid-base balance Spontaneous and mandatory breaths can be combined to meet the minute ventilation target (in other words, intermittent mandatory ventilation) . If the patient is not triggering, the ventilator determines the respiratory frequency, tidal volume, and pressure required to deliver the tidal volume, inspiratory time, and I:E ratio. If the patient is triggering, the number of mandatory breaths decreases and the ventilator chooses a pressure support that maintains a tidal volume sufficient to ensure alveolar ventilation based on a dead space calculation of 2.2 mL/kg ***(Nahla et al, 2018).***

- **Patient-Controlled Ventilation (PCV)**

This approach to ventilatory support takes control of gas delivery from the clinician and places it on the patient. The two modes of ventilation that fall under the classification of patient-controlled ventilation are proportional-assist ventilation (PAV) and neurally adjusted ventilatory assist (NAVA). With both of these modes, the clinician sets the proportion of work performed by the patient, but they do not force a ventilatory pattern. With these modes, patients can breathe rapid and shallow or slow and deep, based on the patient's breathing pattern. These modes may improve patient ventilator synchrony and breathing variability ***(*****Dean,** ***R. Hess 2014).***

- **Proportional-Assist Ventilation (PAV)**

Proportional-Assist Ventilation adjusts airway pressure in proportion to patient's effort. This is accomplished by a positive feedback control that amplifies airway pressure proportionally to instantaneous inspiratory flow and volume. With PAV, the amount of support changes with patient's effort, assisting ventilation with a uniform proportionality between ventilator and patient. Because inspiratory effort is a reflection of respiratory drive, this form of support may result in a more physiologic breathing pattern ***(Niraj Niranjan, 2018).***

- **Neurally Adjusted Ventilatory Assist (NAVA)**

NAVA increases or decreases airway pressure based on the electromyographic activity of the diaphragm (EAdi), what is set on the ventilator is the airway pressure applied for each microvolt change in EAdi. A specially designed nasogastric tube is placed in the esophagus, this tube has 4 EMG (Electromyography) electrodes. Proper placement requires two electrodes on either side of the patient's diaphragm. Maintaining proper placement of the nasogastric tube is a potential problem in the application of NAVA. Even a few centimeters' movement can alter the proper operation of NAVA. Tube position should be assessed regularly. NAVA can be used for invasive or noninvasive ventilation. ***(Heathe et al, 2016).*** An advantage of NAVA over PAV is that it operates efficiently in the presence of auto-PEEP, as patient's effort increases ventilator pressure (work) decreases. With PCV, pressure (work) is constant regard less of effort. With PAV and NAVA, patient's effort and ventilator pressure (work) are related such that when patient's effort increases, there is an increased pressure applied by the ventilator ***(Genebra, 2018).***

- **Mandatory Minute Ventilation (MMV)**

Mandatory minute ventilation (MMV) is a mode intended to guarantee minute ventilation during weaning. If the patient's spontaneous ventilation does not match the target minute ventilation set by the clinician, the ventilator supplies the difference between the patient's minute ventilation and the target minute ventilation. If the patient's spontaneous minute ventilation exceeds the target, no ventilator support is provided. MMV is thus a form of closed-loop ventilation in which the ventilator adjusts its output according to the patient's response. MMV is only available on a few ventilator types used in the United States and its value to facilitate weaning is unclear. MMV can be provided by altering the rate or the tidal volume delivered from the ventilator. Some ventilators increase the mandatory breath rate if the minute ventilation falls below the target level, whereas others increase the level of pressure support when the minute ventilation falls below the target level ***(Guilhermino, 2014).***

- **Airway Pressure-Release Ventilation (APRV)**

Airway pressure-release ventilation (APRV) uses long inflation periods (3-5 s) and short deflation periods (0.2-0.8 s). In addition to APRV, it is known as BiLevel, BIPAP, BiVent, BiPhasic, PCV +, and DuoPAP. Oxygenation is determined primarily by the high pressure level, which is typically set at 20 to 30 cm H_2O, and FIO_2• Ventilation is determined by the frequency with which the pressure releases to the lower pressure, the difference between the high pressure and the low pressure, and the magnitude of spontaneous breathing. The low pressure setting is usually 0 to 5 em H_2 0. Spontaneous breathing can occur at the high pressure and low pressure s ettings, although the time at low pressure is usually too short to allow spontaneous breathing, Because it combines mandatory and spontaneous breaths, APRV is technically intermittent mandatory ventilation ***(Saiphoklang, N et al,, 2018; Sanjeev et al, 2015).***

- **Inverse ratio ventilation (IRV)**

The ratio of inspiratory time (I time) to expiratory time (E time) is known as the I:E ratio. In conventional mechanical ventilation, the I time is traditionally lower than the E time so that the I:E ratio ranges from about 1:1.5 to 1:3.normal I:E ratio during spontaneous breathing, and it is considered physiologically beneficial to normal cardiopulmonary function. inspiratory time during mechanical ventilation to promote oxygenation in patients with ARDS. The inverse I:E ratio in use is between 2:1 and 4:1 and often it is used in conjunction with pressure-controlled ventilation ***(David M. 2017; Ian Fraser et al, 2013).***

2.2.4 Mechanical ventilation parameter

- **Tidal Volume**

Tidal Volume (TV) is the volume of gas delivered to the patient with each breath, The amount of air inspired and expired with each breath, TV is only set for volume controlled modes of ventilation and is usually 8-12cc/kg of body weight, In pressure controlled modes of ventilation the tidal volume was displayed on the ventilator, but it is not set by the clinician, Excessive tidal volumes have been linked to ventilator-induced acute lung injury called volutrauma ***(Ghoneim, 2017).***

- **Rate (frequency)**

Rate (frequency) The set ventilatory rate is the number of breaths delivered to the patient per minute, it is usually between(10- 16 bpm), The actual rate may be higher than the set rate if the patient is initiating spontaneous breaths, Total respiratory rate = patient rate + ventilator rate, Rate is also a determinant of ventilation, and is adjusted in response to the patient's CO_2 levels, Minute ventilation is the rate multiplied by the tidal volume, For adult patients and older children with COPD reduce tidal volume and Reduce respiratory rate for adult patient with ARDS should be reduce tidal volume and increase respiratory rate, For infant and younger children small tidal volume and high respiratory rate, if CO_2 higher than normal rang >45 or 50 mmhg should be increase in RR if CO_2 lower than normal rang <35 should be decrease in RR ***(Contro, 2019).***

- **Oxygen Percentage (O_2%)**

Fraction of inspired oxygen (FiO_2) The percentage of O_2 that Can be Delivered to the patient during mechanical ventilator, breathe or patient breathe can be Adjusted from (21% - 100%), The goal is to provide the lowest FiO_2 requirements while maintaining adequate PaO_2 and SaO_2 in clinical practice the FiO_2 is usually

States at (100%) if the patient oxygenation status is unknown, for infant and specially in premature infant high level of FIO_2 > 60 % should be avoided, supplemental O_2 is administered in response to low (PaO_2 , SPO_2) or indicators of tissue hypoxia, ABG is obtained approximately 20-30 min ***(Claude Lenfant., 2015).***

- **I:E Ratio**

I:E ratio is the ration of inspiratory time-to-expiratory time, it's usually kept in the range between 1:2 to 1:4 ratio, may be used on patient needing additional time for exhalation be cause of the possibility of air trapping and Auto-PEEP. Auto-PEEP is Present when the end expiratory pressure dos not return to base line pressure at the end of expiration, Inverse I:E ratio has been used to correct refractory hypoxemia in ARDS patient with very low compliance ***(Alderdice, F. 2011).***

- **Inspiratory Time**

Definition part of the ventilatory cycle necessary for inspiration, setting. Maintain an I:E of 1:2 or greater (1:3, 1:4, etc.) Calculate the (I Time) Needed for (I:E) Ratio 1:4, The Solution RR = 16/min it's time for each breath.= 60 Second/16 (3.75 Second) (I Time) = [Time for Each Breath]x[I Ratio/(I:E Ratio)].

= [3.75 Sec] x [1 / (I:E Ratio)]= [3.75 Sec] x [1 / (1+4)] ⟹ [3.75 Sec]x[1/ (5)].

= [3.75 Sec] x [0.2] = (0.75 Sec).Inspiratory time is set in parameter but expiratory time actual parameter ***(Willian Owens 2018).***

- **Peak Inspiratory Pressure**

Definition : Reflects airway resistance and lung compliance (work required to move air through the airways and into the alveoli), normal rang (25- 35) mmhg A- Peak inspiratory pressure reached too soon, Airway obstruction, kinking of ETT, circuit, bronchospasm, low lung compliance, pressure limit, resistant. B- Unable to

Reach Peak inspiratory Pressure: ETT, cuff leak, ventilator circuit leak ***(Schönhofer, 2015).***

- **Positive End Expiratory Pressure (PEEP)**

The normal airway pressure at the end of expiration and before inspiration is zero. Application of pressure by the ventilator at this stage of the ventilatory cycle is called PEEP, PEEP aids in propping open alveoli that would otherwise collapse during the expiratory phase, It is a very effective treatment modality for V/Q mismatching caused by atelectasis processes, and is a key component of ventilator therapy for patients with ARDS ***(Blackwood, B, et al 2014).***

A PEEP setting of 5cm H_2O is considered equivalent to the effect of the closed glottis, and is called physiologic PEEP, PEEP it Primarily increase the Functional Residual Capacity of the Lunge by increase Surface area of the alveoli, The larger Surface area allows O_2 to diffuse through the alveolar capillary membrane into the Circulation lead to increase PaO_2 and SaO_2, increase alveolar Ventilation. Therapeutic PEEP levels range from 10 – 35 cm H_2O or more ***(Hemant et al, 2013).***

- **Pause**

Pause time Inspiratory Pause or Plateau, as percentage of total breath cycle Time. After Required gas is delivery after operator Set VT is reached gas remains in the lung and exhalation is blocked during pause time. The use of pause increase the Residence time of gas in the patient lungs, Normally apply 5-10% (***Allen and Mcgrattan, 2013)***

- **Pressure Support**

Pressure support can be used in combination with other ventilatory modes that permit spontaneous breathing. Pressure support works by responding to a patient's inspiratory effort with a positive pressure breath delivered at a set pressure. The patient can draw more volume by contributing muscular effort to the breath, or the ventilator can deliver the entire breath if muscular effort is not sustained. A pressure support breath is pressure controlled, patient triggered, pressure limited, and patient cycled. The volume of a pressure support breath will vary in proportion to the patient's inspiratory effort. Pressure support can be used to compensate for the increased airway resistance of an endotracheal tube, or to facilitate weaning from mechanical ventilation. Pressure support enhances spontaneous tidal volumes and therefore is adjusted in response to CO_2 levels. Pressure support typically ranges from 5 – 30 cm H_2 ***(Lamouret, 2019)***.

- **Inspiratory plateau pressure**

Is the end inspiratory pressure under no flow conditions, such as an inspiratory pause, the inspiratory plateau pressure reflects the pressure needed to distend the alveoli. Plateau pressure eliminates the influence of airway resistance. As lung compliance decreases, inspiratory plateau pressures increases and vice versa ***(Paul, Ellis 2015).***

- **Flow Rate**

Inspiratory flow rate is the volume of gas/minute delivered through the ventilator circuit into the patient lung, inspiratory flow is expressed in liters/minute and determine the (I:E) ratio. To determine the I:E ratio two major parameters must be identified RR , inspiratory time, typically flow rate 40-60 L/minute for adult. Flow rate = MV/IT% ***(Jean-Michel, 2018)***

- **Trigger**

Sensitivity setting of the ventilator is a threshold value for the trigger variable that, when met, starts inspiration. Pressure, volume, flow, or time may be measured by the ventilator and used as a variable to initiate inspiration. Type of trigger, Time-triggered breath is initiated and delivered by the ventilator when a preset time interval, Assist trigger pressure-triggered breath is initiated and delivered by the ventilator when it senses the patient's spontaneous (negative pressure) inspiratory effort ,(-1 to-2) or to -5 in Patient with muscle weakness, Flow-triggered in flow triggering continuous flow passes through the ventilator circuit and returns to the ventilator, e:g delivered Flow = returned flow (1-5) flow triggered is most common used in CPAP to avoid leg time ***(Robert M, 2018)***.

- **Mean airway pressure (MAP)**

Is the average pressure throughout the ventilatory cycle, MAP = the difference between PIP – PEEP this incorporates all of the above pressures in addition to expiratory pressures and any negative pressures generated by the patient's spontaneous attempts at breathing. Normal range 15-2 ***(John et al, 2014).***

- **Flow Rate**

Inspiratory flow rate is the volume of gas/minute delivered through the Ventilator circuit into the patient lung, inspiratory flow is expressed in (Liters/minute) and determine the I:E ratio, To determine the I:E ratio two major Parameters must be Identified RR and Inspiratory Time. Typically flow rate= 40-60 L/minute for Adult. Flow rate = MV/IT% ***(Peter, 2015).***

- **Lung compliance**

Lung compliance the degree of lung expansion per unit pressure change. Abnormally low or high lung compliance impairs the patient's ability to maintain efficient gas exchange. Low compliance typically makes lung expansion difficult, High compliance induces incomplete exhalation, air trapping, and reduced CO_2 elimination ***(Jean-Louis and Serge, 2019; Laura M, et al, 2016).***

Method to measure static and dynamic compliance, obtain corrected expired tidal volume. obtain plateau pressure by applying inspiratory hold or occluding the exhalation port at end-inspiration. obtain peak inspiratory pressure. obtain positive end expiratory pressure (PEEP) level.

Static Compliance = Corrected V T / (Plateau Pressure - PEEP).

Dynamic Compliance = Corrected V T / (Peak Inspiratory Pressure – PEEP).

plateau pressure is the pressure needed to maintain lung inflation in the absence of airflow. peak inspiratory pressure: The pressure used to deliver the tidal volume by overcoming nonelastic (airways) and elastic (lung parenchyma) resistance ***(Gary C. 2008; Walsh, B. K, 2018)***.

2.2.5 Respiratory failure (RF)

Respiratory failure (RF) may be defined as the failure of normal breathing، ventilation and gas exchange in the lungs leading to low oxygen levels in the cells of the body. Respiratory failure may occur acutely or chronically. The chronic forms are usually managed in hospital or in the home. Acute RF and acute exacerbations of the chronic form are likely to be encountered by emergency responders. Respiratory failure may be classified as type 1, where there is failure of carriage of oxygen from the alveoli to the pulmonary capillaries and type 2 where there is a failure of ventilation of the alveoli leading to the build – up of carbon dioxide. An understanding of these two forms is important for the decision to ventilate ***(Jean-Michel, 2018; Nugent and Edriss, 2017; Fan, E., 2017).***

Table 2: Summary of respiratory failure Classification

Classification	Type 1 respiratory failure	Type 2 respiratory failure
Other names	• *Hypoxic respiratory failure* • *Lung failure*	• *Hypercapnic respiratory failure* • *Pump failure*
Main feature	• *Hypoxia and normal $PaCO_2$*	*Hypercapnia and hypoxia*
Typical cause	• *Ventilation/ perfusion mismatch* • *Arteriovenous shunt* • *Gas diffusion impairment*	• *Excessive airway resistance* • *Decreased ventilator drive* • *Respiratory muscle fatigue or failure* • *Abnormal status of the lungs and chest wall*

Adapted from (Markle, 2014)

2.2.6 Protocol for lung protective ventilation

A protocol for lung protective ventilation has been developed by the ARDS clinical network (a network created by the government to evaluate potential therapies for ARDS), and this protocol is shown in Table 3. Note that the tidal volume in this protocol (6 mL/kg) is based on the predicted body weight, which is the body weight associated with normal lung volumes ***(Paul,et al 2017).***

Table 3. Protocol for Lung Protective Ventilation

I. First stage:
1. Calculate patient's predicted body weight (PBW).   *a. Males: PBW = 50 + [2.3 x (height in inches — 60)]*   *b. Females: PBW = 45.5 + [2.3 x (height in inches — 60)].* *2. Set initial tidal volume (VT) at 8 mL/kg PBW.* *3. Add positive end-expiratory pressure (PEEP) at 5 cm H_2o.* *4. Select the lowest FiO_2 that achieves an SPO_2 of 88—95%.* *5. Reduce VT by 1 mL/kg every 2 hrs until V_T = 6 mL/kg.*
Il. Second stage:
1. When V_T = 6 ML/kg measure the end-inspiratory plateau pressure (PpI). *2. If Ppl > 30 cm H_20, decrease VT in 1 mL/kg increments until PpI <30 cm H_20 Or VT = 4 mL/kg.*
III. Third stage:
1. Monitor arterial blood gases for respiratory acidosis. *2. . If pH = 7.15 — 7.30, increase respiratory rate (RR) until pH >7.30 or RR= 35bpm.* *3. If pH < 7.15, increase RR to 35 bpm. If pH is still <7.15 increase VT in 1 mL/kg increments until pH >7.15*
IV. optimal goals:
1. V_T= 6 mL/kg, PpI < 30 cm H_20, SpO_2 = 88 — 95%, pH = 7.30—7.45

Adapted from (www.ardsnet.org 2017)

2.2.7 Pathophysiology and causes of respiratory muscle insufficiency

The respiratory system consists of two parts which can be impaired independently from each other, the lungs and the respiratory pump. The latter is a complex system covering different anatomic structures, the breathing center, the peripheral nervous system, the respiratory muscles, and the thorax, According to this complexity several underlying conditions can cause insufficiency of the respiratory Muscle ***(Edward, 2017***; ***Steven M & Sunil K.(2012).***

Table 4: Pathophysiology and causes of respiratory muscle insufficiency.

Cause for muscle insufficiency	***Category***	***Mechanisms***	***Underlying diseases and/or causes***
Weakness of respiratory muscles	*Respiratory centre Peripheral nerves Respiratory muscles*	*Ischemia, infection, neuritis, nerve damage*	*Encephalitis, diaphragm paresis, Guillain-Barre Syndrome, Critical illness polyneuropathy, Amyotrophic lateral sclerosis, diabetes mellitus, Critical illness myopathy, Ventilator induced diaphragmatic dysfunction, myasthenia, Duchenne muscular dystrophy, post- polio-syndrome, COPD,*
Overload of respiratory muscles	*Airways*	*Ischemia, infection, neuritis, nerve damage Obstruction, hyperinflation, laryngeus recurrens paresis*	*COPD, cystic fibrosis*
	Lung parenchyma	*Reduced compliance Reduced gas exchange area*	*Pulmonary oedema, fibrosis Bleeding,*
	Oxygen transport	*Anemia, methemoglobinemi a Reduced perfusion*	*Bleeding, blood sampling, infection, drugs Heart insufficiency, PAH Pulmonary arterial hypertension, pulmonary emboly*
	Thoracic cage	*Reduced compliance*	*Pleural effusions, scoliosis, post-TBC-syndrome*
	Oxygen consumption	*Increased metabolism*	*Catecholamines, agitation, infection*
	Metabolism		*Hypothyroidism, malnutrition, electrolyte imbalance*

Adapted from (Schönhofer, 2015)

2.2.8 Care of the Artificial Airway

Orotracheal intubation is preferred over nasotracheal intubation. Suction

ing and clear the airway should be maintain the airway clearance and The cuff on the artificial airway should be inflated to 20 to 30 cm H_20 during exhalation to minimize aspiration of secretions and to minimize tracheal injury. However, even at this pressure, micro-aspiration can occur through the longitudinal folds in the cuff. To minimize pooling of secretions above the cuff, deep pharyngeal suctioning should be performed on a regular basis and before movement of the patient. Use the endotracheal tubes with subglottic suction ports may reduce the risk of VAP ***(Dres and Demoule, 2018; Foglia, E, et al 2007).***

Table 5: Elements Commonly Included in a VAP Prevention Bundle

- *Appropriate hand hygiene.*
- *Precautions based on specific infection.*
- *Use noninvasive ventilation.*
- *Head elevated > 30 degrees.*
- *Routine oral care.*
- *Use cuff pressure of 20-30 cm H_2O.*
- *Use inline suction catheters.*
- *Do no routinely change ventilator circuits .*
- *Remove ventilator circuit condensate away from the patient.*
- *Use orotracheal instead of nasotracheal intubation.*
- *Use subglottic suction systems and cuffs that minimize aspiration• .*
- *Rinse nebulizers with sterile water (or saline) between treatments and allow to air dry.*
- *Deliver aerosolized medications using methods that do not break the circuit.*
- *Reduce colonization of gastrointestinal tract; peptic ulcer prophylaxis.*
- *Avoid gastric over distention.*
- *Ensure adequate nutrition.*
- *Perform daily spontaneous awaking trials and spontaneous breathing trials.*
- *Use positive end-expiratory pressure of at least 5em Hp.*
- *Minimize transports out of the unit for diagnostic studies.*

Adapted from (Aykac, K , et al 2017)

2.3 Section Three: Weaning

2.3.1 Definitions

- **Weaning**

Discontinuation of mechanical ventilation can be defined as the process of gradual (weaning) or sudden ventilator support withdrawal in critically ill patients and represents one of the most important challenges in intensive care units, Weaning success means that a patient is able to maintain spontaneous breathing for a prescribed period of time. This usually leads to termination of mechanical ventilation. Weaning from mechanical ventilation can be defined as the process of abruptly or gradually withdrawing ventilatory support ***(David J. Baker, 2016)***.

- **Weaning success**

Defined as absence of ventilatory support 48 hours following the extubation, while the spontaneous breaths are unassisted by mechanical ventilation, supplemental oxygen, bronchodilators, pressure support ventilation, or continuous positive airway pressure may be used to support and maintain adequate spontaneous ventilation and oxygenation. one study shows 15% of mechanically ventilated patients required more than 7 days to be weaned successfully***(Allen and Mcgrattan, 2013)***.

- **Weaning failure**

Is more difficult to define than weaning success, this is because whenever a patient is placed back on the ventilator, the weaning attempt has failed in one form or another. In most studies, weaning failure is defined as either the failure of spontaneous breathing trial (SBT) or the need for reintubation within 48 hours following extubation. Patients who fail the SBT often exhibit the following clinical signs: tachypnea, tachycardia, hypertension, hypotension, hypoxemia, acidosis, or arrhythmias. Physical signs of SBT failure may include agitation, distress, diminished mental status, diaphoresis, and increased work of breathing ***(Dres and Demoule, 2018; Steidl, C, et al, 2017).***

2.3.2 Evaluation of clinical criteria for weaning

The points have evolved as criteria for weaning. The problem that caused the patient to require ventilation must have been resolved.Certain measurable criteria should be assessed to help establish a patient's readiness for discontinuation of ventilation.spontaneous breathing trial should be performed to firmly establish readiness for weaning. There are numerous measures of readiness to wean, some of which are maximal inspiratory pressure, compliance, minute volume, occlusion pressure, work of breathing, oxygen cost of breathing, weaning index integrative weaning index, inspiratory effort quotient. ***(Breul, W. 2013: Deepak, 2016).***

Assessment of the patient's overall clinical condition should include an evaluation of the clinical conditions. depending on the severity of these clinical conditions, they should be corrected or normalized prior to a weaning attempt ***(J.M. Cairo, 2016)***

2.3.3 How do we know if the condition is improving

Improving general condition, fever, etc, Decreasing FiO_2 requirement, Improving breath sounds, Decreasing endotracheal secretions, Improving chest X-rays, Decreased chest tube drainage, bleeding/air bubbles (as the case may be), Improved fluid and electrolyte status (no overload or dyselectrolytemia), Improving hemodynamic status, Improving neurological status, muscle power, airway reflexes/control, Described weaning criteria such as maximal negative inspiratory force, vital capacity measurement are usually impractical. In pediatrics and neonatal age group weaning criteria are generally clinical ***(Botha,L 2012).***

2.3.4 Criteria used to determine readiness for trials of spontaneous breathing.

Spontaneous breathing trials are the primary approach to weaning from ventilatory support for all of these patients, Successful SBT completion of 30 to 120 minute spontaneous breathing trial performed with a low level of CPAP (e.g, 5 cm H_2O) or low level of pressure support (e.g., 5 to 7 cm H_2O) showing adequate respiratory pattern and gas exchange, hemodynamic stability, and the patient comfort ***(Yuan Lei, et al, 2017).***

Monitor the patient's appearance, pulse, oxygen saturation measured by pulse oximeter, and blood pressure; observe the cardiac monitor for arrhythmia. Use the ventilator to monitor respiratory rate, tidal volume, and minute ventilation. If the patient does not tolerate the SBT for at least 30 minutes, reestablish the ventilator settings, and allow the patient to rest for at least a few hours before reattempting another SBT and more detail in table 6 ***(Marik, 2015)***.

Table 6. Criteria used to determine readiness for SBT.

Required criteria
2 .PaO_2/FiO_2 ≥ 150 a or SaO_2 ≥ 90% on FiO_2 ≤ 40% and positive end - expiratory pressure (PEEP) ≤ 5 cm H_2O
2. Hemodynamic stability (no or low dose vasopressor medications, e.g., dopamine at a dose ≤ 5 mcg/kg/min).
Additional criteria
1 .Weaning parameters: respiratory rate ≤ 35 breaths/min, spontaneous tidal volume > 5 ml/kg, negative inspiratory force (NIF) < − 20 to − 25 cm H_2O, f/V T < 105 breaths/min/l
2. Hemoglobin ≥ 8 – 10 mg/dl
3. Core temperature ≤ 38 – 38.5 degrees Celsius
4. Mental status awake and alert or easily arousable

Adopted from Heather et al., (2016)

2.3.5 Patient conditions prior to weaning

Perhaps the first consideration before any weaning attempt is to assess the patient's overall clinical status ***(Chatburn, R, 2012).***

Two important questions pertaining to the patient's clinical condition are, has the patient significantly recovered from the acute phase of the disease or injury that prompted the need for mechanical ventilation, Are there other clinical conditions that may interfere with the patient's ability to sustain the work of spontaneous breathing? Assessment of the patient's overall clinical condition should include an evaluation of the clinical conditions in Table 7, depending on the severity of these clinical conditions, they should be corrected or normalized prior to a weaning attempt ***(David, J, Baker, 2016**; **Patricia, 2015).***

Table 7. Conditions that may hinder a successful weaning outcome

Condition	***Example***
Patient/pathophysiologic	*Fever.*
	Infection.
	Renal failure.
	Sepsis.
	Sleep deprivation.
Cardiac/circulatory	*Arrhythmias.*
	Blood pressure (high or low).
	Cardiac output (high or low).
	Fluid imbalance.
	Anemia.
	Dysfunctional hemoglobin's.
Dietary/acid-base/electrolytes	*Nutritional or caloric deficit*
	Acid-base imbalance.
	Electrolytes imbalance.

Adopted from (Deepak, 2016)

2.3.6 Weaning criteria

Weaning criteria are used to assess the patient, trial weaning is successful if patient meets most of the used criteria, the ventilatory status of a patient may be used to evaluate the readiness and outcome of weaning attempts. weaning success was more likely if the patient can sustain an adequate ventilation. The generally accepted ventilatory weaning criteria include a $PaCO_2$ of less than 50 mm Hg with normal pH, a vital capacity of greater than 10 mL/kg, a spontaneous VT of greater than 5 mL/kg, a spontaneous frequency of less than 35/min, RSBI f/VT of less than 100 breaths/min/L, and a minute ventilation of less than 10 L with satisfactory blood gases ***(Frutos-vivar, 2017).***

2.3.6.1 Ventilatory Criteria

The ventilatory status of a patient may be used to evaluate the readiness and outcome of weaning attempts. Weaning success was more likely if the patient can sustain an adequate ventilation. The generally accepted ventilatory weaning criteria include a $PaCO_2$ of less than 50 mm Hg with normal pH, a vital capacity of greater than 10 mL/kg, a spontaneous VT of greater than 5 mL/kg, a spontaneous frequency of less than 35 breath/min, an f/VT of less than 100 breaths/min/L, and a minute ventilation of less than 10 L with satisfactory blood gases the common weaning criteria are summarized in Table 8 ***(Frutos-vivar, 2017).***

Table 8: Common Weaning Criteria

Category]	*Example*	*Note*
Clinical criteria	*Resolution of acute phase of disease*	
	Adequate cough	
	Absence of excessive secretions	
	Cardiovascular and hemodynamic Stability	
Ventilator criteria	*Spontaneous breathing trial*	*≥Tolerates 20 to 30 min*
	$PaCO_2$	*<50 mm Hg with normal pH*
	Vital capacity	*>10 mL/kg*
	Spontaneous VT	*>5 mL/kg*
	Spontaneous f	*<35/min*
	f/VT	*<100 breaths/min/L*
	Minute ventilation	*<10 L with satisfactory ABG*
Oxygenation criteria	PaO_2 *without PEEP*	*> 60 mm Hg at* FIO_2 *up to 0.4*
	PaO_2 *with PEEP (,8 cm H2O)*	*>100 mm Hg at* FIO_2 *up to 0.4*
	SaO_2	*> 90% at* FIO_2 *up to 0.4*
	PaO_2*/FIO2 (P/F)*	*>150 mm Hg*
	QS/QT	*> 20%*
	$P(A\text{-}a)O_2$	*> 350 mm Hg at* FIO_2 *of 1.0*
Pulmonary reserve	*Vital capacity* *Max. insp. pressure*	*>30 mL/cm* H_2O *Stable or improving* *< 60% while intubated*

Adopted from (Robert E. Hyatt, 2015).

- **Partial pressure of carbon dioxide in arterial blood ($PaCO_2$).**

The partial pressure of carbon dioxide in the arterial blood ($PaCO_2$) is a reliable indicator of the patient's ventilatory status. Weaning from mechanical ventilation should be attempted only when the $PaCO_2$ is less than 50 mmHg with a compensated pH (non-COPD patient). In patients with normal lung functions, the $PaCO_2$ should be within the normal range of 35–45 mmHg and the pH should be between 7.35 and 7.45. however, in patients with COPD, the acceptable $PaCO_2$ may be slightly higher and the pH slightly lower, depending on the patient's baseline normal values prior to mechanical ventilation ***(Hicks, F. D.,& Merritt,, 2014).***

- **Vital Capacity and Spontaneous Tidal Volume(VC & STV)**

The mechanical condition of the lungs may be evaluated by measuring the vital capacity and spontaneous tidal volume. It is generally accepted that the minimal vital capacity and spontaneous tidal volume consistent with successful weaning are 10 mL/kg and 5 mL/kg, respectively ***(Bronagh and Jenifer, 2007).*** The results of 11 studies indicate that spontaneous tidal volume averaged 368 mL in weaned patients but only averaged 277 mL in non-weaned patients If the patient has been receiving full ventilatory support, it is advisable to allow the patient to breathe spontaneously for 3 min under close observation prior to measuring the vital capacity and spontaneous tidal volume. An equilibration period is needed to obtain the spontaneous effort based on the patient's actual respiratory requirement ***(J.M. Cairo, 2016).***

Unlike spontaneous tidal volume, vital capacity requires active patient effort and cooperation. vital capacity measures the maximal amount of volume that the patient can expire following a maximal inspiration. For this reason, its validity is effort dependent, and proper teaching and coaching are required for accurate measurements. Poor effort or inability to follow commands may result in lower than actual vital capacity measurement ***(Jonathon et al, 2011).***

- **Spontaneous Frequency (SF)**

For a successful weaning outcome, the spontaneous frequency should be less than35 breath/min while the corresponding PaCO2 should be less than 50 mmHg frequency of greater than 35/min is associated with rapid shallow breathing. This breathing pattern increases deadspace ventilation and is highly ineffective for gas exchange during spontaneous breathing. a moderate to significant increase in spontaneous frequency after discontinuation of mechanical ventilation is a sign of impending weaning failure as with the spontaneous tidal volume measurement, the patient should be allowed to breathe spontaneously for 3 minute prior to measuring the spontaneous frequency. This allows the patient ample time to normalize the breathing pattern, and thus is more reflective of the patient's response to the respiratory requirement ***(Li et al., 2020; Judithet al, 2016).***

- **Minute Ventilation (MV)**

The patient's minute ventilation (either spontaneous or assisted) should be less than 10 L/min for a successful weaning outcome (assuming the corresponding $PaCO_2$ is normal). A high minute ventilation requirement (10 L) to normalize the $PaCO_2$ implies that the work of spontaneous breathing is excessive. The patient is unlikely to be able to sustain the increased work of breathing once the weaning process begins. An excessive minute ventilation requirement may result from increased carbon dioxide production secondary to an increased metabolic rate, an increase in alveolar dead space, or metabolic acidosis. Causes for increased carbon dioxide production include extensive burn injuries, an elevated body temperature, and sometimes over-feeding, especially with excessive carbohydrate supplements ***(Cairom Jimmy, 2019: Genebra., 2018).***

Alveolar dead space was increased if the alveolar ventilation exceeds the alveolar perfusion (V/Q. 0.8). This condition of dead space ventilation may occur when (1) the alveoli are over ventilated as in hyperinflation of the lungs (e.g, emphysema) and (2) the pulmonary circulation is under perfused (e.g, pulmonary embolism, decreased cardiac output) ***(Andrew et al, 2016).***

2.3.6.2 Oxygenation Criteria (OC)

The oxygenation status of a patient may be used to evaluate the readiness and outcome of weaning attempts. Weaning success was more likely if the patient is adequately oxygenated while receiving partial or no ventilatory support before or during the weaning process. the generally accepted oxygenation weaning criteria include a PaO_2 of greater than 60 mmHg (or SaO_2 90%) on an FiO_2 0.40 or less, a PaO_2/FIO_2 index greater than 150 mm Hg, an intrapulmonary shunt (QS/QT) of less than 20%, and an alveolar-arterial oxygen tension gradient ($P(A\text{-}a)O_2$) less than 350 mm Hg at an FIO_2 of 100% ***(Bissett, B. M et al, 2012).***

- **PaO_2 and SaO_2.**

A PaO_2 of 60 mmHg corresponds to an SaO_2 of about 90%. It is essential to note that in patients with anemia or increased level of dysfunctional hemoglobins (carboxyhemoglobin), the PaO_2 and SpO_2 (pulse oximetry) do not reflect the true oxygenation status of the patient. In those instances, the arterial oxygen content (CaO_2) and arterial oxygen saturation (SaO_2) should be measured and used for clinical decisions. If pulse oximetry is used to monitor a patient's oxygenation status, the pulse oximetry O_2 saturation (SpO_2) should be kept in the mid-90s for allowance of machine inaccuracies, because SpO_2 readings in critical care are accurate to within 2% to 4% of the SaO_2 ***(Jean-Michel, 2018; Kenneth, et al, 2017)***.

- **PaO_2/FIO_2.**

The arterial oxygen tension to inspired oxygen concentration (PaO_2/ FIO_2) or P/F index is a simplified method for estimating the degree of intrapulmonary shunt. A PaO_2/FIO_2 of 150 mmHg suggests acceptable physiologic shunt and compatible to successful weaning trial ***(Edward, 2017).***

- **QS/QT**

The physiologic shunt to total perfusion (QS/QT) ratio is used to estimate how much pulmonary perfusion is wasted. Shunted pulmonary perfusion cannot take part in gas exchange due to mismatch of ventilation (e.g., atelectasis). The T ratio can be calculated using the classic physiologic shunt equation:

$$\frac{QS}{QT} = \frac{CcO2 - CaO2}{CcO2 - CvO2}$$

QS/QT: Shunt percent in %

CcO2: End-capillary oxygen content in vol%

CaO2: Arterial oxygen content in vol%

CvO2: Mixed venous oxygen content in vol%

In clinical settings, a calculated physiologic shunt of 10% or less is considered normal. Shunt of 10% to 20% indicates mild physiologic shunt, and shunt of 20% to 30% shows significant physiologic shunt. Greater than 30% shunt reflects critical and severe shunt. Since physiologic shunt in mechanical ventilation is usually intrapulmonary in origin(inadequate ventilation in relation to pulmonary perfusion), weaning failure becomes likely when spontaneous ventilation cannot keep up with the pulmonary perfusion. For this reason, significant and severe intrapulmonary shunt (QS/QT. 20%) should be corrected before any weaning attempt. P (A-a)O_2 ***(J.M. Cairo, 2016)***.

- **Alveolar-to-arterial partial pressure of oxygen ($P_{(A-a)}O_2$).**

The alveolar-arterial oxygen tension gradient ($P_{(A-a)}O_2$) is used to estimate the degree of hypoxemia and the degree of physiologic shunt. The $P_{(A-a)}O_2$ gradient may be obtained by subtracting the measured PaO_2 from the calculated P_AO_2 value. This gradient is directly related to the degree of hypoxemia or shunt (a larger gradient reflects more severe hypoxemia or shunt). The alveolar-arterial oxygen tension gradient ($P_{(A-a)}O_2$) can be calculated as follows: $P_{(A-a)}O_2 = P_AO_2 - P_aO_2$

$P_{(A-a)}O_2$: Alveolar-arterial oxygen tension gradient in mmHg.

P_AO_2: Alveolar oxygen tension in mmHg

PaO_2: Arterial oxygen tension in mm Hg

On room air, the $P_{(A-a)}O_2$ should be less than 4 mmHg for every 10 years in age.For example, the $P_{(A-a)}O_2$ should be less than 24 mmHg for a 60-year-old patient. on 100% oxygen, every 50 mmHg difference in $P_{(A-a)}O_2$ approximates 2% physiologic shunt. In mechanical ventilation, $P_{(A-a)}O_2$ of less than 350 mm Hg while on 100% oxygen suggests a likelihood of weaning success. $P_{(A-a)}O_2$ of 350 mmHg while on 100% oxygen approximates 14% shunt and values of greater than 350 mmHg may hinder the weaning process. any large $P_{(A-a)}O_2$ gradient (>350 mm Hg) should be corrected prior to the weaning trial ***(Dean R. Hess , 2014).***

2.3.6.3 Pulmonary Reserve

A patient's pulmonary reserve may be assessed by measuring the vital capacity (VC) and maximum inspiratory pressure (MIP). The VC and MIP maneuvers require active patient cooperation, and therefore these two measurements are effort-dependent. Proper explanation, vigorous coaching, and allowance of an equilibration period to stimulate active respiratory drive are the prerequisites for valid and meaningful measurements ***(Genebra, 2018).***

- **Vital Capacity (VC)**

The vital capacity (VC) reflects a patient's pulmonary reserve as it includes three lung volumes inspiratory reserve volume, tidal volume, and expiratory reserve volume. VC measures the maximum amount of lung volume that the patient can exhale following maximal inspiration. typically the patient is instructed to breathe in as deeply as possible and exhale all the air into a spirometer. unlike the forced vital capacity obtained in the pulmonary function lab, this VC maneuver does not require forceful exhalation. For successful weaning, the patient should have a VC of greater than 10 mL/kg ***(Ionescu, 2013).***

- **Maximum Inspiratory Pressure (MIP)**

The maximum inspiratory pressure (also called negative inspiratory force) is the amount of negative pressure that the patient can generate in 20 sec when inspiring against an occluded measuring device (negative pressure manometer). If the patient is alert, explain the procedure and encourage the patient to attempt to inspire as forcibly as possible. In some mechanically ventilated patients, a waiting period without assisted ventilation may be needed to induce mild hypoxia and hypercapnia for the best inspiratory efforts. In addition, the duration of airway occlusion is an important factor in determining the accuracy (individual therapists) and reliability (between therapists) of the MIP measurements. ***(Irwin et al, 2014)*** the MIP is considered a measure of ventilatory muscle strength, and weaning will likely be successful if the patient can generate an MIP of at least 230 cm H_2O. The results of 11 studies indicate that the MIP averaged 237 cm H_2O for weaned patients versus only 230 cm H_2O for non-weaned patients ***(Magalhães, 2018)***.

2.3.6.4 Pulmonary measurements

Static compliance, airway resistance, and dead space to tidal volume (VD/VT) ratio are three measurements that are not dependent on a patient's cooperation or effort. They are used to indicate the amount of pulmonary workload that is needed to support spontaneous ventilation. In general, low compliance, high airway resistance, and high V_D/V_T ratio all contribute to an increased workload. When these undesirable conditions reach the patient's threshold, they may hinder the weaning process and outcome ***(Paul, 2017)***.

- **Static Compliance**

The static lung compliance is measured by dividing the patient's tidal volume (measured at the airway opening) by the difference in the plateau pressure and the PEEP. The lower the compliance, the greater the work of breathing will be. The minimal compliance value consistent with successful weaning is 30 mL/cm H_2O or greater the static lung compliance may be calculated as follows:

$$C\ ST = \frac{\triangle V}{\triangle P}$$

C_{ST}: Static lung compliance in mL/cm H_2O

$\triangle V$: Corrected tidal volume in mL

$\triangle P$: Pressure change (P_{PLAT} - PEEP) in cm H_2O.

- **Airway Resistance**

The airway resistance can be estimated by dividing the difference in the peak inspiratory pressure and the plateau pressure (H_2O) by the constant inspiratory flow (L/sec). The normal range for airway resistance is 0.6–2.4 cm H_2O/L/sec and higher for ventilator patients because of the associated pathological conditions (e.g., bronchospasm) and tubing resistance (e.g. endotracheal tube, ventilator circuit) ***(Ghoneim, 2017; Magalhães et al, 2016).***

Although no critical weaning value for airway resistance has been established for mechanical ventilation, the work of breathing is directly related to the degree of airway resistance. The endotracheal (ET) tube contributes significantly to the airway resistance. The effect of resistance through the tube can be minimized by ensuring that the ET tube is not kinked or the suction catheter of a continuous suction system is not protruding into the tube. Since retained secretions and bronchospasm contribute to the airway resistance, the patient's airways and lungs should be suctioned as needed. Use of bronchodilators may be helpful to reduce the airway resistance in conditions of reversible bronchospasm ***(Dres and Demoule, 2018).***

- **Pressure support ventilation (PSV)**

Has been used extensively to reduce the elastic and non-elastic airflow resistance and to augment the spontaneous tidal volume, the resulting spontaneous tidal volume is directly related to the pressure support level. PSV may be used in the spontaneous breathing mode or in conjunction with other modes of ventilation that include spontaneous breathing (e.g, SIMV). PSV cannot be used in modes of ventilation that do not allow spontaneous breathing. Since airflow resistance is highly variable among patients and at different stages of mechanical ventilation, the pressure support level must be monitored and adjusted accordingly. The initial PSV level should be titrated until a desired spontaneous tidal volume is reach (e.g, 10 to 15 mL/kg) or until the spontaneous frequency decreases to a target value (e.g, 25/min) ***(Sengupta et al, 2018; Judith et al, 2016).***

- **Deadspace/Tidal Volume (V_D/V_T) Ratio**

The dead space to tidal volume (V_D/V_T) ratio indicates the amount of each breath that is "wasted" or not being perfused by pulmonary circulation. The higher the V_D/V_T ratio, the greater the minute volume demand will be. The V_D/V_T ratio can be calculated as the partial pressure of arterial carbon dioxide minus the mean partial pressure of the carbon dioxide in the exhaled air divided by the arterial blood carbon dioxide tension. For a successful weaning outcome, the V_D/V_T ratio should be 60% or less.The dead space to tidal volume (V_D/V_T) ratio can be calculated as follows:

$$\frac{VD}{VT} = \frac{(PaCO2 - PECO2)}{PaCO2} \infty$$

V_D/V_T: Dead space to tidal volume ratio in %.

$PaCO_2$: Arterial carbon dioxide tension in mmHg.

P_ECO_2: Mixed expired carbon dioxide tension in mmHg ***(Robert & Kenneth, 2017)***.

2.3.7 Rapid shallow breathing index (RSBI)

Failure of weaning may be related to the development of a spontaneous breathing pattern that is rapid (high frequency) and shallow (low tidal volume). The rapid shallow breathing index (RSBI) or f/VT index has been used to evaluate the effectively of the spontaneous breathing pattern Rapid shallow breathing is quantified as the f (number of breaths per minute) divided by the VT in liters, and this breathing pattern induces inefficient, dead- space ventilation. when the RSBI or f/VT index is greater than 100 breaths/min/L (rounded from 105 breaths/min/L), it correlates with weaning failure. on the other hand, absence of rapid shallow breathing (f/VT ratio ,100 breaths/min/L), is an accurate predictor of weaning success to measure the f/VT index, the patient is taken off the ventilator and allowed to breathe spontaneously for 3 min or until a stable breathing pattern has been established. The minute expired volume (VE) and spontaneous frequency (f) are measured. The average VT is calculated by dividing the VE by f. The f/VT is calculated by dividing the f (breaths/min) by the average VT (L). The procedure for measuring and calculating the f/VT is outlined in Table 9 ***(Louise Rose, 2014; Ayka et al., 2017).***

Table 9. Procedures to Obtain the f/V_T Ratio

Procedures
1. Allow the patient at least 3 min to stabilize the spontaneous breathing pattern (ventilator frequency must be off and PSV should not be used if tolerated by patient)
2. Measure expired volume and respiratory frequency for one min.
3. Divide minute volume by frequency (f) to obtain an average tidal volume (VT) in liter.
4. Divide f by VT to obtain f/VT index (breaths/min/L).

Adapted from (Emma H. Baker, 2018)

2.3.8 Weaning procedure

The spontaneous breathing trial (SBT) is the major diagnostic test to deter- mine if patients can be successfully extubated and weaned from mechanical ventilation. Low level pressure support (PS), continuous positive airway pressure (CPAP), or automatic tube compensation (ATC) may be used along with SBT to augment a patient's spontaneous breathing efforts. based on the results of the sixth International Consensus Conference on Intensive Care Medicine, synchronized intermittent mandatory ventilation (SIMV) should be avoided as a stand-alone weaning modality. however, SIMV remains an effective tool in providing partial ventilatory support during continuous MV ***(Hemant et al, 2013).***

2.3.8.1 Spontaneous Breathing Trial (SBT)

Once a decision is made to proceed with weaning, the patient may be discontinued from full ventilatory support and placed on a spontaneous breathing mode via the ventilator or T-tube for up to 30 minutes. oxygen and low level pressure support may be used to supplement oxygenation and augment spontaneous breathing. The criteria for passing an SBT include normal respiratory pattern, adequate gas exchange, and hemodynamic stability. The results of six studies show that only 13% of patients who successfully passed the SBT and were extubated required reintubation ***(Prasad, N. et al, 2017).***

There is no difference in terms of successful SBT among patients undergoing stand-alone SBT, SBT with low level of pressure support, and SBT with CPAP or automatic tube compensation. Since patients who fail the SBT do so within the first 20 to 30 minutes of SBT, there is no need to use an extended SBT. Table 3 describes the procedure for the spontaneous breathing trial and other partial ventilatory support procedures. Note that SIMV is used to provide partial ventilatory support and it is not recommended as a stand-alone weaning modality ***(Jonathon et al, 2011; Bösel, J. 2017).***

2.3.8.2 Failure of SBT

Patients who fail the SBT often do so within the first 20 to 30 minutes of the trial. They also exhibit the following clinical signs and symptoms: agitation and anxiety, diminished mental status, diaphoresis, cyanosis, and evidence of increased work of breathing. Clinical data that correlate with failure of SBT are summarized in Table 10 ***(Morton, P. G, 2013).***

Table 10: Clinical Criteria and Thresholds Related to SBT Failure PaO_2

$PaO_2 \leq 60$ mm Hg on $F_IO_2 \geq 50\%$ SaO_2.
$SaO_2 < 90\%$ on $F_IO_2 \geq 50\%$.
$PaCO_2 > 50$ mmHg or an increase in $PaCO_2 > 8$ mmHg from baseline of SBT.
SBT pH < 7.32 or a decrease in pH ≥ 0.07 from baseline of SBT.
F/VT > 100 breaths/min/L (rounded from 105).
Respiratory rate > 35 breaths/min or increase by ≥50% from baseline of SBT.
Heart rate > 140 beats/min or increase by ≥ 20% from baseline of SBT
Systolic BP > 180 mm Hg or increase by ≥ 20% from baseline of SBT
Systolic BP < 90 mm Hg
Presence of cardiac arrhythmias

Adapted from (**Dean** ***R. Hess, 2014).***

2.3.8.3 Pressure Support Ventilation

Pressure support ventilation (PSV) or similar adjuncts (e.g, proportional pressure support, volume-assured pressure support) may be applied during weaning. PSV helps to reduce the airflow resistance imposed on the patient by the endotracheal tube and ventilator circuit. some clinicians advocate weaning with pressure support as a stand-alone mode. Regardless of the weaning approach used, it is advisable to provide full ventilatory support at night to allow the patient to rest. (Weaning with PSV is done by starting the pressure support level at 5 to 15 cmH_2O and adjusting it gradually (up to 40 cm H_2O) until a desired spontaneous VT (10 to 15 mL/kg) is obtained. some practitioners titrate the pressure support level until a desired spontaneous frequency is reached, typically 25/min or less. This approach is clinically relevant since an increased spontaneous tidal volume corresponds with a decreased spontaneous frequency. If the patient tolerates the weaning process well, the pressure support level is gradually decreased by 3 to 6 cm H_2O increments until a level of close to 5 cm H_2O is reached. Extubation may be considered when the patient's blood gases and vital signs remain satisfactory ***(Blackwood,B, et al 2014; Dräger Medical. 2015)***.

Table 11: Spontaneous Breathing Trial (SBT) and Partial Ventilatory Support Procedures

Procedure	Steps
SBT	*1. May use T-tube, CPAP, or automatic tube compensation* *2. Let patient breathe spontaneously for up to 30 min* *3. May use low level pressure support (up to 8 cm H_2O for adults and 10 cm H_2O for pediatrics) to augment spontaneous breathing؛* *4. Assess patient;* *5. If patient tolerates step (4), consider extubation when blood gases and vital signs are satisfactory. Return patient to mechanical ventilation to rest if necessary.*
SIMV (not recommended as a stand-alone mode for weaning)	*1. Reduce SIMV (ventilator) frequency by 1 to 3 breaths per min.* *2. Monitor SpO2, obtain ABG as needed.* *3. Reduce SIMV frequency further until a frequency of 2 to 4/min is reached. This may take only hours for patients with normal cardiopulmonary functions but days for those with abnormal functions؛* *4. If patient tolerates step (3), consider extubation when blood gases and vital signs are satisfactory.*
PSV	*(1) PSV may be used in conjunction with spontaneous breathing or SIMV mode؛* *(2) Start PSV at a level of 5 to 15 cm H_2O (up to 40 cm H_2O) to augment spontaneous VT until a desired VT (10 to 15 mL/kg) or spontaneous frequency (≤25/min) is reached؛* *(3) Decrease pressure support (PS) level by 3 to 6 cm H_2O intervals until a level of close to 5 cm H_2O is reached؛* *(4) If patient tolerates step (3), consider extubation when blood gases and vital signs are satisfactory.*

Adapted from(Blackwood, B, et al, 2014)

- **Automatic Tube Compensation**

Automatic tube compensation (ATC) is a mode in the Evita 4 ventilator that reduces the airflow resistance imposed by the artificial airway (endotracheal or tracheostomy tube). It allows the patient to have a breathing pattern as if breathing spontaneously without an artificial airway. This type of compensation may facilitate breathing efficacy and reduce the work of breathing throughout the weaning process**.** ***(Donn and Sinha, 2012)***

2.3.8.4 Other Modes of Partial Ventilatory Support

- **Synchronized intermittent mandatory ventilation (SIMV)**

The SIMV can be used to alleviate the need to alternate the patient on T-tube and ventilatory support. Using SIMV to shift the work of breathing from the ventilator to the patient is accomplished by progressively reducing the mandatory SIMV frequency (usually 1 to 3 breaths per minute at each step). Arterial blood gases (or SpO_2) may be measured after 30 min or more at that setting. If the pH remains near normal (above 7.30 or 7.35). the SIMV frequency is further reduced in steps until a frequency of 2 to 4/min is reached. The pace of SIMV weaning is dictated by the patient’s clinical condition and tolerance ***(Irwin et al, 2014; Lindahl, 2012).***

Sometimes SIMV and PSV are used together in patients who have failed the spontaneous breathing trial or have done poorly with SIMV or PSV alone. Under these circumstances, there are other modes of ventilation that provide partial ventilatory support. These modes are volume support, volume-assured pressure support, mandatory minute ventilation, and airway pressure-release ventilation. for a more detailed discussion on these modes, Operating Modes of Mechanical Ventilation ***(Jonathon et al., 2011).***

- **Volume support (VS) and volume-assured pressure support (VAPS)**

Are a form Of PSV that "guarantees" a preset tidal volume. In VS, the pressure support level is adjusted automatically to achieve the target tidal volume. In VAPS, it guarantees a preset tidal volume by incorporating inspiratory pressure support ventilation (PSV) with conventional volume-assisted cycles (VAV). Unlike typical PSV, VAPS assures stable tidal volume in patients with irregular breathing patterns. By decreasing the frequency, the work of breathing is shifted from the ventilator to the patient ***(Allen and McGrattan, 2013; Hemant et al, 2013).***

Mandatory minute ventilation (MMV) is a form of SIMV in which the minute ventilation is guaranteed. The ventilator adjusts the frequency automatically to achieve the target minute ventilation. By decreasing the MMV level, the patient assumes more spontaneous breathing ***(Blackwood, B, et al, 2014).***

- **Airway pressure-release ventilation (APRV)**

APRV has two pressure levels, the higher airway pressure (e.g., 10 cm H_2O) and the lower release pressure (usually 0 cm H_2O). The tidal volume is determined by the pressure gradient between the airway pressure and the release pressure. In APRV**,** exhalation occurs during pressure release and inhalation occurs when the pressure returns to the airway pressure. Weaning may be done by decreasing the frequency of pressure release. When the frequency of pressure release is zero, the patient is essentially on a CPAP mode ***(*Dean*, R. Hess 2014).***

2.3.9 Weaning protocol

Weaning protocol and clinical practice guidelines for weaning are primarily used to outline the standard of care for the purpose of weaning from mechanical ventilation. In general, they often include three elements. The patient condition in which weaning may be attempted, the detailed process of weaning, and the evaluation of weaning outcomes. There are many weaning protocols published in the literatures or developed by individual hospitals or departments. Each of them can be useful when the elements of weaning are incorporated with sound clinical reasoning and implementation. The criteria in the weaning protocol should be used as guidelines only and must not be carried out using a "cookbook" approach. Individual patient differences must also be considered since disease processes and patient characteristics are two of many variables that may affect the outcomes of a weaning protocol. Table 12 provides a weaning protocol for mechanical ventilation ***(J.M. Cairo, 2016: Marcel Dekker, 2011).***

Table 12: Weaning protocol for mechanical ventilation

Step	Criteria	Result
1	*Does the patient show:* • *Evidence of some reversal of underlying cause for ventilatory failure?* • *Presence of inspiratory effort?* • *Hemodynamic stability? (absence of myocardial ischemia, hypotension, use of vasopressor)* • *Adequate oxygenation and acid-base status? (PaO_2/F_1O_2 .150 mmHg, PEEP < 8 cm H_2O and pH ≥7.25) light sedation or better?*	*If yes to all five questions, proceed to step 2. If NO to any one question, postpone weaning until next day*
2	*Perform and measure rapid shallow breathing index (RSBI or f/VT) with mandatory frequency turned off and pressure support ≤8 cm H_2O, PEEP ≤5cm H_2O, measurements taken following ≥3 min of spontaneous breathing .Is RSBI (f/V_T) , 100 breaths/min/L*	*If yes, proceed to step 3. if no, postpone weaning until next day.*
3	*Can patient tolerate: Spontaneous breathing trial for up to 30 minutes without termination?*	*if yes, proceed to ventilator discontinuance or evaluate for extubation. if no, repeat weaning until next day.*

Adapted from (Cederwall, and Ringdal, 2018)

2.3.10 Signs of weaning failure

The weaning process has been started, the previously described weaning criteria should be monitored closely to ensure that the patient is tolerating the weaning attempt. When the mechanical ventilatory support is decreased, part of the work of breathing is shifted to the patient. The goal for the patient is to maintain the work of spontaneous breathing and adequate oxygenation. If the patient tolerates the increased work of breathing and the weaning criteria remain within acceptable limits, then the amount of ventilatory support (e.g., SIMV frequency, pressure sup- port level) should again be decreased. This process is repeated if the patient tolerates the decrease of ventilatory support ***(Janice et al., 2015).***

The weaning process should be stopped if the patient shows signs of muscle fatigue or ventilatory failure. early signs of weaning failure include tachypnea, use of accessory muscles, and paradoxical abdominal movements. It is important to evaluate and apply clinical data in conjunction with the patient's clinical presentations. Patients may hyperventilate due to hypoxia, pain, anxiety, or inappropriate ventilator settings. It is a grave mistake to reduce ventilatory support simply because the $PaCO_2$ shows hyperventilation. Other indications that the patient cannot maintain the work of breathing may include dyspnea, chest pain, chest-abdomen asynchrony, diaphoresis, and delirium ***(Shehab, et al., 2018).***

Some specific indicators of weaning failure are listed in Table 13 If the patient does not tolerate the weaning procedure, the patient should be returned to full ventilatory support and be allowed to rest. The patient should then be reassessed in order to determine the cause of weaning failure. Appropriate therapies may then be applied before attempting the weaning process again ***(Morton, 2013)***.

Table 13: Indicators of weaning failure

Blood Gases	*Increasing PaCO2 (50> mm Hg)*
	Decreasing PaO2/FIO2(<150mm Hg)
	Decreasing pH (<7.30)
	Decreasing PaO2 (<60 mm Hg)
	Decreasing SpO_2 (<90%)
Vital Signs	*Changing blood pressures (20 mmHg systolic or 10 mm Hg diastolic)*
	Increasing heart rate (by 20/min, or >110/min)
	Abnormal ECG (presence of arrhythmias)
Respiratory Parameters	*Decreasing V_T (<250 mL)*
	Increasing f (>30/min)
	Increasing f/VT (>100 breaths/min/L)
	Decreasing MIP (<-20 cm H_2O)
	Decreasing static compliance (<30 mL/cm H_2O)
	Increasing V_D/V_T (>60%)

Adapted from (J.M. Cairo, 2016)

2.3.11 Criteria for weaning failure

Table 14 presenting criteria for weaning failure

Table 14: Criteria for weaning failure

Clinical criteria	***Laboratory criteria Increase***
• *Diaphoresis* • *Nasal flaring* • *Increasing respiratory effort* • *Tachycardia (increase in heart rate >40 bpm)* • *Cardiac arrhythmias.* • *Hypotension* • *Apnea*	• *Increase of $PetCO_2$ >10 mm Hg* • *Decrease of arterial pH <7.32* • *Decline in arterial pH > 0.07 PaO_2 60 > mm Hg with an FiO_2 > 0.40(PaO_2/FiO_2 ratio < 150)* • *Fall in SpO_2 > 5%*

Adapted from (Allen and Mcgrattan, 2013)

2.3.12 Causes of weaning failure

Aside from the pathological conditions that lead to the need for mechanical ventilation, weaning failure may occur when the work of spontaneous breathing becomes too great for the patient to sustain. Weaning failure is generally related to increase of airflow resistance, decrease of compliance, or respiratory muscle fatigue ***(Andrew et al., 2016).***

- **Increase of Airflow Resistance**

Normal subjects using an endotracheal (ET) tube have an increase of 54% to 240% in the work of breathing, depending on the size of the ET tube and ventilator flow rate, An 8-mm ET tube has a cross-sectional area of 50 mm^2, which is slightly smaller than the average cross-sectional area of the adult glottis (66 mm^2), the narrowest part of the airway, To minimize the effects of an artificial airway on airflow resistance, ET tubes of size 8 or larger should be used when it is appropriate to the patient's size.

In addition, the ET tube may be cut to about an inch from the patient's lips to minimize the airflow resistance contributed by the length of the ET tube. Other strategies for decreasing airway resistance can easily be done by periodic monitoring of the ET tube for kinking or obstructions by secretions, or other devices attached to the ET tube such as a continuous suction catheter, heat and moisture exchanger, or end-tidal CO_2 monitor probe. ***(Suzan, 2017)*** Endotracheal suctioning to remove retained secretions and use of bronchodilators to relieve bronchospasm have also been used successfully to reduce the airflow resistance ***(David, J. Baker, 2016)***.

- **Decrease of Compliance**

Abnormally low lung or thoracic compliance impairs the patient's ability to maintain efficient gas exchange. Low compliance makes lung expansion difficult and, it is a major contributing factor to respiratory muscle fatigue and weaning failure. In situations where the compliance gradually decreases (e.g, ARDS), The resultant refractory hypoxemia and increased work of breathing may lead to muscle fatigue and ventilatory failure. When this occurs to a patient undergoing a weaning trial, a return to the mechanical ventilator is almost inevitable. Table 8 shows some examples that lead to a decreased compliance measurement ***(Louise Rose, 2014).***

- **Respiratory Muscle Fatigue**

The muscles used in respiration, like other muscles, become deconditioned and may even atrophy with prolonged disuse.The ventilated patient's respiratory muscles may not be used while on the ventilator، especially if muscle relaxants, heavy sedation, or both have been part of the care plan. A retraining period to exercise and strengthen the respiratory muscles may be necessary before ventilatory support can be discontinued. Respiratory work is a product of transpulmonary pressure (P_{TP}) and tidal volume (V_T). Studies have been done to evaluate the relationship between the work of breathing and a patient's ability to sustain adequate spontaneous ventilation ***(Carter, 2012).***

$$\text{Work of breathing} = PTP \times VT$$

2.3.12 Clinical conditions that decrease the compliance

Low compliance measurements are usually related to conditions that reduce the patient's functional residual capacity. Patients with noncompliant lungs often have a restrictive lung defect, low lung volumes, and low minute ventilation. This condition may be compensated for by an increased frequency. Table 15 shows some examples that lead to a decreased compliance measurement ***(Jonathon et al, 2011; Magalhães et al., 2016).***

Table 15: Clinical conditions that decrease the compliance

Type of Compliance	***Clinical Conditions***
↓ *Static compliance*	*Atelectasis.*
	ARDS.
	Tension pneumothorax.
	Obesity.
	Retained secretions in lungs.
↓ *Dynamic compliance*	*Bronchospasm.*
	Kinking of ET tube.
	Airway obstruction.
	Retained secretions in airways.

Adapted from (Linda, 2014)

2.3.13 Terminal weaning

Terminal weaning is defined as withdrawal of mechanical ventilation that results in the death of a patient. Decisions to withdraw life-support measures (e.g, mechanical ventilation, nutritional support) have become more common. This trend is partly due to the public's awareness of the quality of life issue, and their knowledge that death is an inevitable process in spite of medical advances, state of the art medical equipment, and pulmonary rehabilitation strategies ***(Umesh Kumar, 2011).***

It is also partly due to the availability of living wills, advanced directives, and other options available to the patient and family members. When terminal weaning is considered, four concerns must be evaluated and discussed, where appropriate, with the patient and family members. Patient's informed request, medical futility, reduction of pain and suffering, and fear and distress ***(Heather et al, 2016).***

- **Prior to Withdrawal**

Prior to withdrawal of mechanical ventilation, all immediate caregivers who are uncomfortable with the process should be offered an opportunity to withdraw from the case. The patient's pastor or hospital-based chaplain should be notified. The room should provide a quiet atmosphere and unlimited visitations. All invasive monitoring devices/alarms and unnecessary lines and tubes should be removed. The equipment and supplies that remain should include only the basic vital sign monitoring devices, oxygen therapy, and intravenous access for administration of analgesics and sedatives ***(Eskandar and Apostolakos, 2007)***.

- **Withdrawal**

During the withdrawal process, the family members should be offered an opportunity to stay with the patient.

The attending physician and chaplain are encouraged to be present. Analgesics and sedatives should be provided in sufficient quantity for patient comfort and relief of anxiety. The ventilator settings may be adjusted to provide minimal support (e.g., oxygen and humidity only) while the patient is still intubated. If the ventilator is turned off at this point, the patient is extubated and put on an oxygen mask to minimize prolonged hypoxia, the airway is suctioned to ease patient's breathing efforts. It is important to document the events following completion of terminal weaning, per physician's pronouncement ***(Hicks, F. D.,& Merritt,, 2014)***.

2.3.14 Weaning from short-term ventilation (WFSTV)

Who are intubated for surgical procedures, for an acute exacerbation of an underlying lung disease that can be easily reversed, and for airway protection during an acute neurological event (e.g, drug overdose). It is important to evaluate the reason the patient was initially intubated to be certain that mechanical ventilation is no longer indicated ***(Cairom Jimmy, 2019).***

Weaning within a short period of time is desirable because physiological changes caused by the mechanical ventilation begin within 72 hours ***(Patricia, 2013)*** . Less than 3 days, Often used for elective, procedures, respiratory distress related to disease processes such, as congestive heart failure or trauma ***(David,W Change 2013)***

Weaning procedures may vary slightly from hospital to hospital, but general guidelines remain the same. For instance, weaning is generally initiated in the morning when the patient is rested. The patient is made comfortable, and the nurse elevates the HOB. Pharmacological agents for comfort, such as bronchodilators or sedatives, are administered as indicated. Sedation should be minimized to provide best odds for a successful weaning trial ***(Heather, et al 2016).***

Table 16: Guidelines for weaning from short-term ventilation

Readiness Criteria

- *Hemodynamically stable, adequately resuscitated, and not requiring vasoactive support*
- *SaO2 greater than 90% on FiO2 40% or less, PEEP 5 cm H2O or less*
- *Chest radiograph reviewed for correctable factors; treated as indicated*
- *Metabolic indicators (serum pH, major electrolytes) within normal range*
- *Hematocrit more than 25%*
- *Core temperature more than 36°C and less than 39°C*
- *Adequate management of pain/anxiety/agitation*
- *No residual neuromuscular blockade*
- *ABG values normalized or at patient's baseline*
- *Weaning Intervention*
- *Reduce ventilator rate, then convert to pressure-support ventilation (PSV) only.*
- *Wean PSV as tolerated to 10 cm H2O or less.*
- *If patient meets tolerance criteria for at least 2 hours on this level of support and meets extubation criteria (see later), may extubate.*
- *If patient fails tolerance criteria, increase PSV or add ventilator rate as needed to achieve ―rest‖ settings (consistent respiratory rate <20 breaths/min) and review weaning criteria for correctable factors.*
- *Repeat wean attempt on PSV 10 cm after rest period (minimum, 2 hours). If patient fails second wean trial, return to rest settings and use ―long-term‖ ventilation weaning approach.*

Weaning Intervention

- *Reduce ventilator rate, then convert to pressure-support ventilation (PSV) only.*
- *Wean PSV as tolerated to 10 cm H2O or less.*
- *If patient meets tolerance criteria for at least 2 hours on this level of support and meets extubation criteria (see later), may extubate.*

- *If patient fails tolerance criteria, increase PSV or add ventilator rate as needed to achieve "rest" settings (consistent respiratory rate <20 breaths/min) and review weaning criteria for correctable factors.*
- *Repeat wean attempt on PSV 10 cm after rest period (minimum, 2 hours). If patient fails second wean trial, return to rest settings and use"long-term" ventilation weaning approach.*

Tolerance Criteria:

- *If the patient displays any of the following, the weaning trial should be stopped and the patient returned to ―rest‖ settings.*
- *Sustained respiratory rate greater than 35 breaths/min.*
- *SaO_2 less than 90%.*
- *Tidal volume 5 mL/kg or less.*
- *Sustained minute ventilation greater than 200 mL/kg/min.*
- *Evidence of respiratory or hemodynamic distress: (Labored respiratory pattern, increased anxiety, diaphoresis, or both, sustained heart rate greater than 20% higher or lower than baseline, systolic blood pressure exceeding 180 mm Hg or less than 90 mm Hg*

Extubation Criteria

- *Mental status: alert and able to respond to commands.*
- *Good cough and gag reflex and able to protect airway and clear secretions*
- *Able to move air around the endotracheal tube (ETT) with cuff deflated and end of tube occluded*

Adapted from (Dorrie &Patricia, 2015).

2.3.15 Weaning From Long-Term Ventilation (WFLTV)

The process of long-term weaning often takes weeks. It incorporates gradual and progressive conditioning for respiratory and body muscles using a multidisciplinary team approach. Success with whole body conditioning with emphasis on upper body strength and respiratory muscle function has improved ventilator liberation, and aggressive physiotherapy is necessary. Usually, the entire process is complicated, and it involves multiple delays and setbacks. During long-term weaning, the patient may fail a weaning trial and should then be rested on the ventilator up to 24 hours before another trial is attempted. The rest period allows for recovery of the respiratory muscles. Patients who fail a weaning trial often exhibit rapid, shallow breathing patterns consistent with their respiratory muscle weakness. Regular reevaluation of the weaning plan by the multidisciplinary team, coupled with continuous communication with the patient and family, is necessary ***(Yuan Lei, et al 2017).***

- **Goals of long-term mechanical ventilation (LTV)**

The overall goal of LTMV at home or other alternative care sites is to improve the patient's quality of life by providing the following environmental attributes, Enhancing the individual's living potential, Improving physical and physiological level of function, Reducing morbidity, Reducing hospitalizations, Extending life, Providing cost-effective care, Because patients require different levels of care, it is desirable for every patient to progress to their point of maximum activity and take an active role in their own care. If this is accomplished, then their psychosocial well-being will also improve ***(Paul, et al, 2017; Ian Fraser et al., 2013)***.

Table 17: Guidelines for weaning from long-term ventilation

Patients on mechanical ventilation for longer than 72 hours or those having failed short-term weaning often display significant decondition- ing as a result of acute or chronic complex illness, or both. These patients usually require a period of "exercising" respiratory muscles to regain the strength and endurance needed for successful return to spontaneous breathing. Goals for this process are:

- *To have the patient tolerate two to three daily weaning trials of reduction in ventilatory support without exercising to the point of exhaustion.*
- *To rest the patient between weaning trials and overnight on ventilator settings that provide diaphragmatic rest, with minimal or no work of breathing for the patient*

Readiness Criteria

- *Same as for short-term ventilation, with emphasis on hemodynamic stability, adequate analgesia/sedation (record scores on flow sheet), and normalizing volume status.*

Weaning Intervention.

- *Transfer to PSV mode, adjust support level to maintain patient's respiratory rate at less than 35 breaths/min.*
- *Observe for 30 minutes for signs of early failure (same tolerance criteria as with short-term ventilation).*
- *If tolerated, continue trial for 2 hours, then return patient to "rest" settings by adding ventilator breaths or increasing PSV to achieve a total respiratory rate of less than 20 breaths/min.*
- *After at least 2 hours of rest, repeat trial for 2 to 4 hours at same PSV level as previous trial. If the patient exceeds the tolerance criteria (listed in table 3), stop the trial and return to "rest" settings. In this case, the next trial should be performed at a higher support level than the "failed" trial.*
- *Record the results of each weaning episode, including specific parameters and the time frame if "failure" observed, on the bedside flow sheet*
- *The goal is to increase the length of the trials and reduce the PSV level needed on an incremental basis. With each successive trial, the PSV level may be decreased by 2 to 4 cm H2O, the time interval may be increased by 1 to 2 hours, or both, while keeping the patient within tolerance parameters. The pace of weaning is patient specific, and tolerance may vary from day to day. Review readiness criteria for correctable factors daily and each time the patient "fails" a weaning trial.*
- *Ensure nocturnal ventilation at "rest" settings (with a respiratory rate of <20 breaths/min) for at least 6 hours each night until the patient's weaning trials demonstrate readiness to discontinue ventilatory support.*

Discontinuing Mechanical Ventilation

The patient should be weaned until ventilator settings are FiO2 40% or more, PSV 10 cm H2 O or less, and PEEP 5 cm H2 O or less. Once these settings are well tolerated, the patient should be placed on continuous positive airway pressure 5 cm H2 O or (if tracheostomy in place) on tracheostomy collar. If the patient meets tolerance criteria over the first 5 minutes, the trial should be continued for 1 to 2 hours. If clinical observation and ABG values indicate that the patient is maintaining adequate ventilation and oxygenation on this "minimal" support, the following options should be considered:

- *If the patient meets extubation criteria (table 3), this step should be attempted.*
- *If the patient is on tracheostomy collar, the trials should be continued two to three times per day with daily increases in time on tracheostomy collar by 1 to 2 hours per trial until total time off the ventilator reaches 18 h/d. at this point, the patient may be ready to remain on tracheostomy collar for longer than 24 hours unless the tolerance criteria are exceeded.*
- *Ventilator weaning is considered successful once the patient achieves spontaneous ventilation (extubated or on tracheostomy collar) for at least 24 hours.*

Adapted from (Patricia, 2013)

2.3.16 Nursing Management of the Patient Requiring Prolonged MV

2.3.16.1 Mechanical Ventilation

- **Successfully weaning from the ventilator**

Perform respiratory assessment/chest auscultation, protocols to facilitate continued weaning, perform chest use physiotherapy/ambulation, manage secretions, provide for periods of uninterrupted sleep ***(Ahanatha, 2015).***

- **Nutrition**

Consult with dietician, balance metabolic needs with nutritional intake, weigh patient daily, monitor regular bowel elimination, monitor electrolytes and renal function as appropriate, administer bowel regimen medications as ordered, along with adequate hydration, provide early nutritional support by enteral or parenteral feeding, monitor actual delivery of nutrition daily with I & O calculations ***(Jeanine, et al, 2016).***

- **Functional**

Collaborate with physiotherapy and occupational therapy teams to strengthen the patient and improve conditioning, Establish a daily routine with the patient, Use splints and supports to keep extremities in a neutral position, encourage patient to meet basic needs as able, use tools to assess cognitive function, provide materials to facilitate communication, for example, note pads‹ calendar, pictures, encourage family to assist with simple tasks that are part of the care required, for example, range-of-motion activities, bathing ***(Ahanatha, 2015; Burns, N. & Grove, 2011).***

- **Prevent complications/promote safety**

Ensure all alarms are activated on the monitoring system and ventilator, monitor skin integrity and take measures to prevent skin breakdown, Assess and document skin integrity at least every shift. Turn patient side to side every 2 hr;

reassess bony prominences for evidence of pressure injury. Assess hemodynamic effects of initiating positive-pressure ventilation (e.g, potential for decreased venous return and cardiac output). Assess hemodynamic effects of initiating positive-pressure ventilation (e.g, potential for decreased venous return and cardiac output). Monitor for signs of infection (e.g, pneumonia), remove any unnecessary devices such as Foley catheter, vascular access devices, Strictly adhere to evidence-based practices, such as hand washing، meticulous oral care, and isolation techniques ***(Joseph Varon, 2016).***

2.3.17 Weaning classification

Simple weaning and extubation with the first SBT, includes patients who successfully pass the initial SBT and are successfully extubated on the first attempt weaning (no need to reinstitute ventilator support within 48 hr. of extubation). Difficult weaning Successful weaning and extubation after initial failure but at the latest with the 3rd SBT or within 7 days of mechanical ventilation after the first failed SBT. Prolonged weaning Successful weaning after at least 3 failed SBT's or MV longer than 7 days after the first failed SBT 3. Prolonged weaning, includes patients who require more than three SBT or >7 days of weaning after the first SBT ***(Paradis et al, 2014).***

2.3.18 Methods of ventilator weaning

There are several weaning methods that are effective in liberating the patient from the ventilator, with no one method proving to be superior. These include synchronized intermittent mandatory ventilation (SIMV), pressure support (PS), T-piece, or continuous positive airway pressure (CPAP). current research recommends the use of the spontaneous breathing trial (SBT) in which the patient can demonstrate the ability to breathe without assistance of the mechanical ventilator. when using the SBT method, the goal is to gradually improve the patient's respiratory muscle strength and endurance to support spontaneous breathing ***(Suki& Hubmayr, R, 2014;Starnes, &Palokas, 2017)***

- **Synchronized intermittent mandatory ventilation mode SIMV**

The SIMV mode was initially heralded as the optimal weaning mode, allowing some spontaneous breathing (to prevent respiratory muscle atrophy) while providing a backup rate. Weaning with the SIMV method entails a gradual reduction in the number of delivered breaths until a low rate is reached (usually 4 breaths/min). The patient is then extubated if all other weaning criteria are met ***(Jonathon et al, 2011).***

- **Continuous positive airway pressure method CPAP**

CPAP entails breathing through the ventilator circuit with a small amount of (or zero) positive pressure. The use of CPAP instead of the use of a T-piece for weaning is controversial. often, the decision to use one over the other is determined by observing the patient's response or is simply based on the clinician's preference ***(Hugh et al, 2015).***

- **Pressure-Support Ventilation Mode (PSV)**

Low levels of PSV decrease the work of breathing associated with ETTs and ventilator circuits. Weaning using the PSV mode entails a progressive decrease in IPL to 5 to 10 cm H2O based on the patient maintaining an adequate tidal volume (6 to 12 mL/kg) and a respiratory rate of fewer than 25 breaths/min. PSV is associated with less work of breathing than with volume modes, so longer weaning trials may be tolerated. The 5-cm H2O IPL is thought to overcome the work of breathing through the ETT and ventilator tubing. Typically, the IPL is reduced by 2 cm H2O daily or twice daily following the patient's response to the ventilator change. Tolerance of PSV weaning is assessed as any weaning mode by assessing the patient's response to changes in respiratory rate, SaO_2 and heart rate, along with observing for fatigue.

There is support for use of CPAP, T-piece, or even PSV during a spontaneous breathing trial before extubation because each is an effective method for the weaning readiness trial ***(Krishnan, J, et al, 2015)***.

- **Neurally adjusted ventilatory assist (NAVA)**

Neurally adjusted ventilatory assist (NAVA) is a novel mode, which is based on neural respiratory output. NAVA utilizes the electrical activity of diaphragm (EAdi) to assist the patients' breathing. Evidence suggests that NAVA may have a role in weaning difficulty, by reducing patient-ventilator dyssynchrony. Neurally adjusted ventilator assist (NAVA) could help optimize weaning, (NAVA) in a selected population of tracheostomised patients weaning, Herein we report the first case from India describing the use of NAVA in successfully weaning a patient with difficult weaning who was intubated for the management of acute respiratory failure due to scrub typhus ***(Lamouret, 2019)***

- **T-Piece Trial**

The T-piece is connected to the patient at the desired FiO_2 (usually slightly higher than the previous ventilator setting). The patient’s response and tolerance to the trial are continuously observed. The duration of T-piece trials is not standardized, and some clinicians extubate if an initial trial of 30 minutes ends with acceptable ABG values and patient response. Increasing frequency and duration of T-piece trials builds the patient’s endurance, with periods of rest on the ventilator between extended trials. When the latter method is used, the patient is generally deemed ready to be extubated after 24 successive hours on a T- piece ***(Robert, 2017).***

2.3.19 Psychological aspect of weaning

Preparing the patient psychologically to come out of ventilator is the primary sential step of weaning , The patient must be approached with compassion, empathy, and patience, stay with the patient initially and communicate in a calm and reassuring manner. Explain the weaning, procedure as often as necessary and reduce anxiety, When a patient is alert and well oriented, certainly he, suffers from anxiety and fear of withdrawal of support, that he was receiving so far, which maintained his life, He must be strongly reassured that if he feels any, difficulty and is unable to continue, he was supported adequately before fatigue develops. ***(Hicks, F. D., Merritt, 2014)***.

Nurses must be informed about the weaning plan and he has to be explained that weaning is an exercise training program for the respiratory muscles that they was gradually taking over more of the WOB, He must be informed that he has to give feedback about how he feels physically and emotionally throughout the weaning, The physician must develop a mode of communication with the patient that he effectively participates mostly by signs and facial expressions ***(Wang, et al,, 2015).***

2.3.20 Evidence-Based Ventilator Weaning Guidelines

According to American college of chest physicians (ACCP) society of critical Care medicine (SCCM) & American association for respiratory care (AARC) (ACCP-SCCM-AARC) the evidence-based ventilator weaning guidelines presents in the following table 18:

Table 18: Evidence-based ventilator weaning guidelines

1. *In patients requiring mechanical ventilation for more than 24 h, a search for all causes that may be contributing to ventilator dependence should be undertaken. Reversing all possible ventilatory and non-ventilatory issues should be an integral part of the ventilator discontinuation process.*
2. *Patients receiving mechanical ventilation for respiratory failure should undergo a formal assessment of discontinuation potential if the following criteria are satisfied: evidence for some reversal of the underlying cause for respiratory failure, adequate oxygenation and pH, hemodynamic stability, and capability to initiate an inspiratory effort.*
3. *Formal discontinuation assessments for patients receiving mechanical ventilation for respiratory failure should be done during spontaneous breathing rather than while the patient is still receiving substantial ventilatory support.*
4. *Removal of the artificial airway from a patient who has successfully been discontinued from ventilatory support should be based upon assessments of airway patency and the ability of the patient to protect the airway.*
5. *Patients receiving mechanical ventilation for respiratory failure who fail an SBT should have the cause for the failed SBT determined. Once reversible causes for failure are corrected, subsequent SBTs should be performed every 24 h.*
6. *Patients receiving mechanical ventilation for respiratory failure who fail an SBT should receive a stable, non-fatiguing, comfortable form of ventilatory support.*
7. *Anesthesia/sedation strategies and ventilator management aimed at early extubation should be used in postsurgical patients.*
8. *Weaning/discontinuation protocols designed for non-physician health care professionals should be developed and implemented by ICUs. Protocols aimed at optimizing sedation should also be developed and implemented.*
9. *Tracheostomy should be considered after an initial period of stabilization on the ventilator when it becomes apparent that the patient will require prolonged ventilator assistance*
10. *Unless there is evidence for clearly irreversible disease (e.g, high spinal cord injury، advanced amyotrophic lateral sclerosis), a patient requiring prolonged mechanical ventilatory support for respiratory failure should not be considered permanently ventilator-dependent until 3 months of weaning attempts have failed.*
11. *When medically stable for transfer, patients who have failed ventilator discontinuation attempts in the ICU should be transferred to those facilities that have demonstrated success and safety in accomplishing ventilator discontinuation.*
12. *Weaning strategy in the prolonged mechanically ventilated patient should be slow-paced، and should include gradually lengthening self-breathing trials.*

Adapted from (Marik, 2015)

2.4 Section Four: Extubation

2.4.0 Extubation

This should take place following a successful spontaneous breathing trial. The patient should be awake, able to cough and protect his/her own airway, The patient should be sat upright, and suction should be available. The cuff of the endotracheal tube can be deflated slightly to allow an audible air leak. The absence of an audible cuff leak may suggest some laryngeal oedema but is not a contraindication to extubation. The patient's oropharynx can be suctioned to remove excess secretions prior extubation. The endotracheal tube then can be removed swiftly with the patient giving a large cough ***(Haugdahl, 2016).***

Whichever mode or combination of modes is used for weaning, extubation cannot occur until several criteria are met based on short-term or long-term ventilation. Before extubation, the patient must be able to maintain his or her own airway, as evidenced by an appropriate level of consciousness and the presence of cough and gag reflexes. In all patients, but especially in those with a history of difficult intubation or reactive airway disease, the cuff-leak test should be performed before extubation. This entails deflation of the tube cuff (after suctioning of the oropharynx) and a brief period of occluding the ETT in order to demonstrate an air leak with patient inspiration. Absence of a leak can indicate edema and may predict laryngeal stridor after extubation. If the cuff-leak test fails, the patient may be given corticosteroids to reduce edema for 24 to 48 hours and then be reassessed for cuff leak. A direct visualization of the trachea with a bronchoscope may be performed before extubation to determine whether the edema has resolved ***(Marik, 2015).***

Table 19: Guideline removal of the Endotracheal Tube.

Indications

- *When airway control provided by the endotracheal (ET) tube is no longer necessary (the patient should be able to maintain a patent airway and generate adequate spontaneous ventilation to maintain normal gas exchange).*
- *When an acute obstruction of the ET tube cannot be cleared rapidly. Reintubation or other appropriate techniques must be used to maintain effective gas exchange.*
- *When further medical care of the patient is explicitly declared futile (tube removal is allowed).*

Contraindications

- *No absolute contraindications to removal of the ET tube have been reported*

Hazards/Complications

- *Possible hazards and complications include hypoxemia and hypercapnia from airway obstruction, resulting from edema of the trachea, vocal cords, or larynx, laryngospasm, bronchospasm, aspiration, respiratory muscle weakness, hypoventilation, excessive work of breathing, development of atelectasis, and post-extubation pulmonary edema.*

Limitations of Methodology

- *Predicting an extubation outcome is sometimes very difficult. It is of significant clinical importance because both extubation delay and unsuccessful extubation are associated with poor patient outcomes. The literature on extubation readiness is limited by few validated objective measures to accurately predict the extubation outcome for an individual patient.*

Assessment of Extubation Readiness

- *Patients should be able to maintain spontaneous ventilation adequately and should not require high levels of positive pressure or oxygenation to maintain adequate arterial blood gas oxygenation n (PaO_2 /$FI\ O_2$ >150 to 200 on an FIO_2 ≤0.4 to 0.5 and low levels of PEEP ≤ 5 to 8 cm H_2O; pH ≥7.25).*
- *Successful completion of 30- to 120-minute SBT performed with low level of CPAP (e.g, 5 cm H_2O) or a low level of PS (5 to 7 cm H_2O) demonstrating adequate respiratory pattern and gas exchange*
- *Other examples of measurements that can be used to assess extubation readiness include spontaneous respiratory rate, rapid shallow breathing index (RSBI), vital capacity (VC), peak expiratory flow (PEF), transdiaphramatic pressure gradient (Pdi), maximum inspiratory pressure (MIP), work of breathing (WOB), airway occlusion pressure ($P_{0\cdot1}$), maximum voluntary ventilation (MVV), and sustained maximal inspiratory pressures (SMIP).*
- *Adequate respiratory muscle strength.*
- *Patients with artificial airways in place to facilitate treatment of respiratory failure should be considered for extubation when they have met weaning criteria.*

Assessment of Outcome

- *Patient assessment and a physical examination should follow removal of the ET tube to ensure adequate spontaneous ventilation and adequate oxygenation through the natural airway and to ensure that reintubation is not necessary.*
- *Some patients may require post-extubation support or intervention to maintain adequate gas exchange independent of controlled mechanical ventilation. These adjunctive measures may include NIV, CPAP, aerosolized racemic epinephrine, heliox, and possibly diagnostic bronchoscopy.*

Monitoring

- *Appropriately trained personnel.*
- *Frequent evaluation of vital signs, assessment of neurologic status, patency of airway, auscultatory findings, WOB, and hemodynamic status.*

Adapted from (J.M. Cairo , 2016)

2.4.1 Patients at high risk of extubation failure

Failed extubation (FE) is considered to have occurred when reintubation or respiratory assistance is needed within 48 hours of a scheduled extubation, failed extubation also prolongs the duration of MV and thus causes a longer stay in the ICU. This has as a consequence; with the longer resulting hospital stay, other complications increase, such as the need for tracheotomy, the incidence of pneumonia and pulmonary damage induced by MV, such as Chronic heart failure, Age >65 years,

More than one failed weaning trial, More than one comorbidity, PaCO2 >45 after extubation, Weak cough, upper airway obstruction, Voluminous secretions ***(Paul, et al, 2017).***

2.4.2 The cuff leak test

The cuff leak test is performed in patients suspected of having laryngeal edema, The cuff of the endotracheal tube is deflated; if there is no laryngeal edema, the patient should be able to breathe around the tube has approximately a 30 % chance of developing post-extubation stridor however the risk is negligible in patients with a negative cuff leak test, The degree of leak can be quantified by comparing the returned tidal volume before and after the cuff is deflated.

A cuff leak of less than has been shown to be associated with an increased risk the cuff leak test should be performed before extubation in the following circumstances, Traumatic intubation, Prolonged intubation; i.e. longer than 7 days, Patients with head and neck trauma, Head and neck surgery, Patients with previous failed extubation accompanied by stridor, Patients with airway edema (e.g., angioedema) ***(Marik, 2015; Steidl, C, et al, 2017).***

2.4.3 Corticosteroids for the Prevention of Post-extubation Stridor

Endotracheal intubation is frequently complicated by laryngeal edema, which may present as post-extubation stridor or respiratory difficulty or both. Ultimately, post-extubation laryngeal edema may result in respiratory failure with subsequent reintubation. Demonstrated the systemic corticosteroids reduce the risk of post-extubation stridor, methylprednisolone injection (multi-dose or single dose) during the 24 h prior to extubation. Treatment with methylprednisolone significantly reduced the risk of post-extubation stridor and the need for reintubation ***(Ouellette, et al, 2017).***

Chapter Three: Objectives and Hypothesis of the study

3.1 Objectives of the study

3.1.1 General objective

To assess the existing knowledge and practice among intensive care nurses toward weaning criteria from mechanical ventilation at public hospitals in Sana'a City-Yemen.

3.1.2 Specific objectives

1. To identify the level of knowledge about screening of respiratory, hemodynamic and readiness toward weaning criteria from MV.
2. To examine other screening readiness toward weaning criteria from MV.
3. To verify the level of knowledge about modes of weaning intervention from MV.
4. To explore the level of knowledge about recommendation parameters of weaning intervention from MV.
5. To describe the level of knowledge toward tolerance criteria and extubation for weaning from MV.
6. To determine the level of practice among nurses towards weaning criteria from MV.

3.2 Hypothesis

1. There is no statistically significant differences between demographic characteristics and nurses knowledge toward weaning criteria from MV.
2. There is no statistically significant differences between demographic characteristics and nurses practice toward weaning criteria from MV.
3. There is no statistically significant differences between the courses training and nurses knowledge toward weaning criteria from MV.

4. There is no statistically significant differences between the courses training and nurses practice toward weaning criteria from MV.

CHAPTE1R 4: RESEARCH METHODOLOGY

4.1. Study Setting

The study was done in intensive care units (ICU) in four public hospitals in Sana'a City, Yemen that include (Al-Thowrah, Al-Sabeen, Al-Kuwait and Al-Jomhury hospitals). All hospitals provide primary, secondary and tertiary healthcare to all Yemeni people.

The reasons for choosing these hospitals because each hospital has intensive care units and patients under of the mechanical ventilation and they are referral hospitals.

4.2. Study Design

A descriptive, cross-sectional study was carried out to assess knowledge and practice of ICU nurses toward weaning criteria from MV at public hospitals in Sana'a city –Yemen.

4.3 Population and sample of the Study

All nurses with various educational backgrounds and working in ICU at public hospitals in Sana'a City, during the data collection period were enrolled in the study.

4.4 Sample Size Determination

The sample size was determined through use the EpiCalc program, 2000 (Sample - Precision-Single rate) taking into consideration the following;

The sample size to knowledge and practice was calculated as a follows: the population of the study were all nurses working in ICU at four public hospitals (Al-Thowrah hospital, Al-Sabeen, Al-Kuwait, and Al-Jomhury hospital) was 220 nurse, precision (3%) and 95% confidence level. The final sample size was 93 Yemeni nurses.

4.5 Sampling Technique

A stratified random sampling was applied to select the sample size from 4 major public hospitals. After official approvals obtained from the previously selected settings, the researcher obtained lists of nurses' currently working in the study settings via random sampling methods. The list was reviewed and nurses meeting the inclusion criteria were included in the study to select from the total population (N)= 220 nurses were subdivided according to hospitals (Al-Thowrah hospital n = 105, Al-Jomhury hospital n= 45, Al-Kuwait hospital n= 37 and Al-Sabeen hospital n= 33).

Calculation, the sample size from each hospital the following formula was used:

$$\frac{n}{N} * K = sample\ size\ to\ each\ hospital$$

- n = (sample size)
- N= (study population)
- k= (population of each hospital)

A stratified random sampling to select sample size from each hospital as follows:

Study setting	Total of Population	The sample size
Al-Thowrah hospital	105	44
Al- Jomhury hospital	45	19
Al-Kuwait hospital	37	16
Al-Sabeen hospital	33	14
Total	**220**	**93**

4.6 Inclusion and exclusion criteria

4.6.1 The inclusion criteria were included:

- All Yemeni male and female nurses working in the ICU who had an educational certificate that agree to participate in this study during the study period were enrolled.

- Nurses who had a duration of working 1 year and more.

4.6.2 The exclusion criteria were included:

All nurses who are not fulfilling the above inclusion criteria.

4.7 Data Collection Methods and Tools

The variables of the study which included demographic characteristics of ICU nurses, training courses or degree and knowledge and practices toward the weaning criteria from MV were collected from 1st June to 30th March 2019.

Data collection methods: The data collection methods were included;

1. A self-administered questionnaire was used to collect data on demographic characteristics of ICU nurses, training courses or degree and knowledge toward the weaning criteria from MV.
2. The observational method was used to gain insight into what was happening in practice. The observational method involved the collection of data that specify the practice or events selected for observation and was conducted in participants' natural environments**.**

Data collection tools: The researcher developed his own tool to assess the knowledge and practices toward the weaning criteria from MV. The tools which all had been constructed based on the several literature review **(*Ouellette, et al 2017; Haugdahl, 2016; Burns, S. M 2012; Contro, 2019; J.M. Cairo, 2016; Robert* & Kenneth*, 2017; David W chang, 2013; Cynosure ; Hicks, F. D., Merritt,, 2014).***

. The data collection tools were included;

1. ***Questionnaire****:* A structured questionnaire was administered to assess the knowledge of ICU nurses (Appendix- A). A close-ended questionnaire with an information letter and consent form attached and handed to ICU nurses by

the researcher. A code number was applied. The questionnaire consisted of thirty questions. The questionnaire divided into the following sections:

- **Section one:** Demographic characteristics of nurses; this part contains the following: (ICU type, sex, marital status, age, level of education, duration of working). The questions number from (1 to 6).
- **Section two:** degree or courses training in ICU, attending training on weaning from MV, protocol of weaning from MV, diploma in respiratory therapy. The questions number from (1 to 4).
- **Section three:** knowledge of ICU nurses toward weaning criteria from mechanical ventilation, which included twenty questions. This part was comprised of the following sections:
    - **Part I:** Knowledge of ICU nurses about screening of respiratory, and hemodynamic. The questions number from (1 to 4).
    - **Part II:** Knowledge of ICU nurses about readiness weaning criteria from MV. The questions number from (5 to 7).
    - **Part III:** Knowledge of ICU nurses about modes of weaning intervention from MV. The questions number from (8 to 10).
    - **Part IV:** Knowledge of ICU nurses about recommendation parameters of weaning intervention from MV. The questions number from (11 to 13).
    - **Part V:** Knowledge of ICU nurses about tolerance criteria for weaning from MV. The questions number from (14 to 17).
    - **Part VI:** Knowledge of ICU nurses about extubation. The questions number from (18 to 20).

The questionnaire prepared in English language and translated into Arabic using translation and back-translation techniques by two specialists, all nurses were received an Arabic version questionnaire. If some of the items in the questionnaire were not clear. The questionnaires were filled in the presence of the researcher and participants were free to ask any questions or clarifications.

The questionnaire was filled during working hours; consent forms and filled questionnaires were placed into sealed by the researcher and taken from each unit daily. All of the collected data has checked by the researcher daily for completeness and finally.

2. ***The observation checklist***: was used to assess the actual nurses' practice. During the three shifts, each nurse cared for mechanically ventilated patients was observed by the researcher for about 1-4 hours, the time is selected randomly whereby the researcher stays around ICU. Within these hours, the nurses were occupied with patients care practice. Observed nurses' time was conveniently selected and were not aware that they were being observed.

The observation checklist include the twenty six observations. The observation checklist is divided into the following section:

- **Part I:** Practice of ICU nurses about readiness for weaning criteria from MV. The checklist questions number from (1 to 9).
- **Part II:** Practice of ICU nurses about weaning intervention from MV. The checklist questions number from (10 to 17).
- **Part III:** Practice about extubation. The checklist questions number from (18 to 26).

4.8 Validity and Reliability of the Tools

- **Validity**

Validity is the extent to which a test measures what it is intended to measure ***(Burns & Grove 2011).*** To maximize validity, representative questions for each category were designed and evaluated against the desired outcome. To establish the validity of the instrument, a pilot study was conducted before starting the data collection of the questionnaire.

The face validity: defined as the appearance that a tool is adequate for its intended purpose. It is achieved by clarity and organizing the instruments in categories with a logical sequence ***(Burns & Grove 2011).*** An expert panel were agreed on the face and content validity of the questionnaire. The questionnaire was validated because the same questionnaire was used during the pilot study and it measured what it was supposed to measure.

The content validity: is inclusion of questions representative of the qualities of the test attempts to measure appropriate domain ***(Burns & Grove 2011).*** The questionnaire and an observation checklist were adopted from previously validated and reliable studies ***(Ouellettem, et al, 2017; Haugdahl, 2016; Burns, 2012; Contro, 2019; J.M. Cairo, 2016)*** and from weaning criteria from MV guidelines ***(Robert &*** **Kenneth*, 2017; David, W. Chang, 2013; Cynosure, 2013).***

The validity of the Arabic version of the questionnaire and an observation checklist were sent to 5 experts to assess the clarity and relevance of the questionnaire to the objectives of the study. Experts included two academic staff in critical and medical-surgical nursing and three ICU nurse specialist, the ICU respiratory therapist, and a registered nurse who has worked in the ICU for 6 years and more.

All comments on the tools were taken into consideration, as a result, some modification for some items were done.

- **Reliability**

Reliability is defined as the degree to which an assessment tool produces stable and consistent results ***(Burns & Grove 2011).*** For the most purposes reliability coefficient ≥0.7 are considered satisfactory. The, overcoming the distribution of the questionnaire to measure the reliability can be achieved by using Cronbach's Alpha through the SPSS software ***(Bal Kumari, 2017)*** and the general reliability for all items equal (0.86). This range is considered high, the result ensures the reliability of the questionnaire**.**

4.9 Pilot Study

The piloted of the questionnaire and the observation checklist was performed before starting the data collection as a pretest to point out weaknesses in wording, translation to Arabic, predict response rate, determine the time needed to fill the questionnaire and identify areas of vagueness and to test the validity and suitability of the questionnaire. A pilot study was done in the study setting on 10% of nurses working in the ICU on items in a questionnaire and observation checklist. Following the pilot study, minimal modifications to the layout and presentation of the instrument were made. The piloted nurses were excluded from the final study sample.

4.10.Data Management and Analysis

Once the questionnaires were collected, a codebook was developed to provide numerical results for analysis. Information from the tool was original data. All available data organized into pie chart and cross-tables were used to provide an overall and coherent presentation and description of data. A packaged computer analysis program, statistical package for the social science (SPSS 21.0) used for statistical analysis of this data. Descriptive statistics were used to interpret the demographic data: age, sex, working experiences in ICU and training and types of ICU. Descriptive statistics including frequency and percentage for categorical variables and the mean and standard deviation (SD) for numerical variables.

To find between variables, Chi-square test (x^2) for association was used for testing association between categorical variables. *t*-test was used to examine the differences between two variables and when dependent variable was continuous and independent variable was categorical and continuous variable was normally distribution. One way-ANOVA was used to examine the differences between more than two variables when dependent variable was continuous and independent variables were categorical and continuous variable was normally distribution. Furthermore the Cronbach's Alpha was used to determine reliability of data collection tools. *P*-value <0.05 was considered significant.

All items on the data collection tools (questionnaire and observation checklist) were weighted with the digits 0 and 1. Weighting (1) represented adherence to accepted ICU nurse knowledge and practice employed to weaning criteria from MV. whereas 0 represented non adherence to accepted ICU nurse knowledge and practice employed to weaning criteria from MV. The above weight was converted into % ranging from 0 - 100%.

Nurses who selected a correct choice from a certain item were considered to have knowledge or practice on that item. Nurses who selected the wrong choice or don't know from a certain item were considered to have no knowledge on that item. Each right answer was given one score and each wrong answer was given zero scores. Nurses who select the not done from a certain item were considered to have no practice on that item. Not corrct done was given one score. Each correct done was given two score.

The levels of knowledge and practice were classified based on the following quotation: 80/100x50=40 this equal to (50%) then the poor level was assigned to nurses who got (0%-49%), 80/100x75=60 this equal to (75%) then the moderate level (50%-75%) and good (>75%) ***(Bal Kumari, 2017)***.

4.11 Study Variables/Operational Definition

4.11.1 Study variables:

- ***Independent variables:*** Demographic charactristics and ICU training (course training in ICU, weaning criteria from MV and diploma in respiratory therapy).
- ***Dependent variables:*** Knowledge and practice of ICU nurses toward the weaning criteria from MV.

4.11.2 Operational definitions:

- **Intensive care unit:** A special area in a hospital, where critically ill patients or highly dependent patient, who need close and frequent observation, can be cared for by qualified and special trained staff working under the best possible condition.
- **Intensive care nurse:** Any nurse working in general ICU, cardiac ICU, surgical ICU, medical ICU, neuro ICU, and pediatric ICU at public hospitals.
- **ICU training:** This is a formal ICU training for nurses working under the best possible condition to a care-dependent patient who needs close and frequent observation.

- **Knowledge:** Information and understand that are gained through education or experiences ***(Oxford dictionary, 2010).*** For this study knowledge refers to the response of the nurse regarding the weaning criteria from MV.
- **Practice:** is ability to perform and do something well that has been learned for this study practices is refers to the nursing actions done by the nurses on the subject regarding the weaning criteria from MV***(Oxford dictionary, 2010).***
- **Weaning:** Weaning is the process of decreasing the amount of support that the patient receives from the mechanical ventilator, so the patient assumes a greater proportion of the ventilatory effort ***(Tobin and Jubran, 2006).***
- **Weaning criteria from MV**: Refers as a weaning begins when we recognize that the patient has recovered adequately from acute respiratory failure. Thereafter, clinical assessments are needed to determine the patient's readiness for discontinuation of ventilatory support and extubation ***(Bal Kumari, 2017)***.

4.12 Ethical Considerations

Approval of the study was obtained prior to carrying out this study from the college of medical sciences of Al-Razi University. A cover letters were sent to principles of hospitals to obtain approval to conduct this study (Appendix -B). The purpose and benefits of the study was explained to participants.

The consent was taken orally from all participating nurses in the study (Appendix-A). All nurses also have the right to refuse to participate or to withdraw from the study without any effect on their working.

CHAPTER FIVE: RESULTS

5.1 Demographic characteristics of ICU nurses

Table 5.1 shows the demographic characteristics of nurses, Most of the nurses (75.3%) had working experience from 1-5 years, and (65.6%) of them were in age ranged from 20-30 years, About two third (64.5%) of the nurses had diploma degree, while more than half of the nurses (54.8%) were married, and (51.6%) of the nurses were male, moreover (28%) of the nurses working in general ICU.

Table 5.1: Demographic characteristics of ICU nurses (N= 93).

Demographic characteristics	**F**	**%**
Sex		
• Male	**48**	**51.6**
• Female	45	48.4
Age group		
• 20-30	**61**	**65.6**
• 31-40	30	32.3
• >40	2	2.2
Marital status		
• Single	42	45.2
• Married	**51**	**54.8**
Level of education		
• Diploma degree	**60**	**64.5**
• Bachelor degree	29	31.2
• Master degree	4	4.3
Type of ICU		
• General ICU	**26**	**28.0**
• Pediatric ICU	15	16.1
• Emergency ICU	13	14.0
• Surgical ICU	7	7.5
• Medical ICU	13	14.0
• Other (Neuro, Nephro, Cardio, burn,) ICU	19	20.4
Work experience (years)		
• 1 - 5 years	**70**	**75.3**
• 6 - 10 years	16	17.2
• >10 years	7	7.5

5.2 ICU Training among nurses

Regarding the responses of ICU nurses toward training, (40.9%) of the nurses had course training in ICU and (16.1%) of nurses had training program on the weaning criteria from MV, whereas (17.2%) of them had a diploma in respiratory therapy, All of the nurse mention that they never write weaning protocol in the hospital. Table 5.2.

Table 5.2: ICU Training among nurses (N= 93).

Statement	Responses			
	Yes		No	
	F	%	F	%
Course training in ICU	**38**	**40.9**	55	59.1
Writing weaning protocol in the hospital.	0	0	93	100
Courses training in weaning criteria from MV	15	16.1	78	83.9
Diploma in respiratory therapy	16	17.2	77	82.8

5.3 Knowledge of nurses toward WC from MV

5.3.1 Screening readiness of respiratory and hemodynamic toward WC from MV

- ***Knowledge of nurses about screening readiness respiratory and hemodynamic toward WC from MV:***

The majority of the nurses (80.6%) knew the hemodynamic stability for weaning criteria required high dose vasoactive support. And the most of the nurses (78.5%) knew a criteria used to assess patient of spontaneously breathing tolerance is the respiratory pattern, whereas the adequate oxygenation when the ratio of paO_2 > 150 to 200 mmHg (72.0%). also the respiratory screening to wean from MV is PEEP ≤ 2-7 cm H_2O, pH ≥7.50, RR ≤ 7 bpm (65.6%), Table 5.3.

Table 5.3: Knowledge of nurses about screening readiness respiratory and hemodynamic (N= 93)

Statement	Responses			
	Correct answer		Incorrect answer	
	F	%	F	%
A criteria used to assess patient of spontaneously breathing tolerance is?				
A. Adequate gases exchange.	61	65.6	32	34.4
B. Respiratory pattern.	**73**	**78.5**	20	21.5
C. Hemodynamic stability.	41	44.1	52	55.9
D. Mental status within normal.	27	29.0	66	71.0
Adequate oxygenation for weaning means?				
A. $SpaO_2$ ≥ 60 mmHg with FiO_2 < 0.4.	36	38.7	57	61.3
B. Ratio of paO_2 > 150 to 200 mmHg.	**67**	**72.0**	26	28.0
C. FiO_2 ≤ 0.4 to 0.5 and pH≥ 7.25.	16	17.2	77	82.8
D. SaO_2 > 90 % at FiO_2 up to 0.4.	19	20.4	74	79.6
The hemodynamic stability for weaning criteria?				
A. Systolic blood pressure > 80 - < 160 mmHg.	66	71.0	27	29.0
B. Hematocrit more than 25%.	24	25.8	69	74.2
C. Heart rate < 140 beat/minute.	44	47.3	49	52.7
D. High dose vasoactive support.	**75**	**80.6**	18	19.4
The respiratory screening to wean from MV is?				
A. Respiratory rate < 35 breath/min.	60	64.5	33	35.5
B. PEEP ≤ 2-7 cm H_2O, pH≥7.50, RR ≤ 7 bpm.	**61**	**65.6**	32	34.4
C. PH ≥7.32 - < 7.45, PEEP ≤ 5 cm H_2O.	53	57.0	40	43.0
D. Temperature more than 36 C◦ - less than < 39 C◦.	40	43.0	53	57.0

- ***Total knowledge about screening readiness respiratory and hemodynamic toward WC from MV:***

The results of the study toward total knowledge of the nurses about screening readiness respiratory and hemodynamic showed that (51%) of the nurses had correct knowledge, while (49%) of the nurses had incorrect knowledge. Figure 5.1.

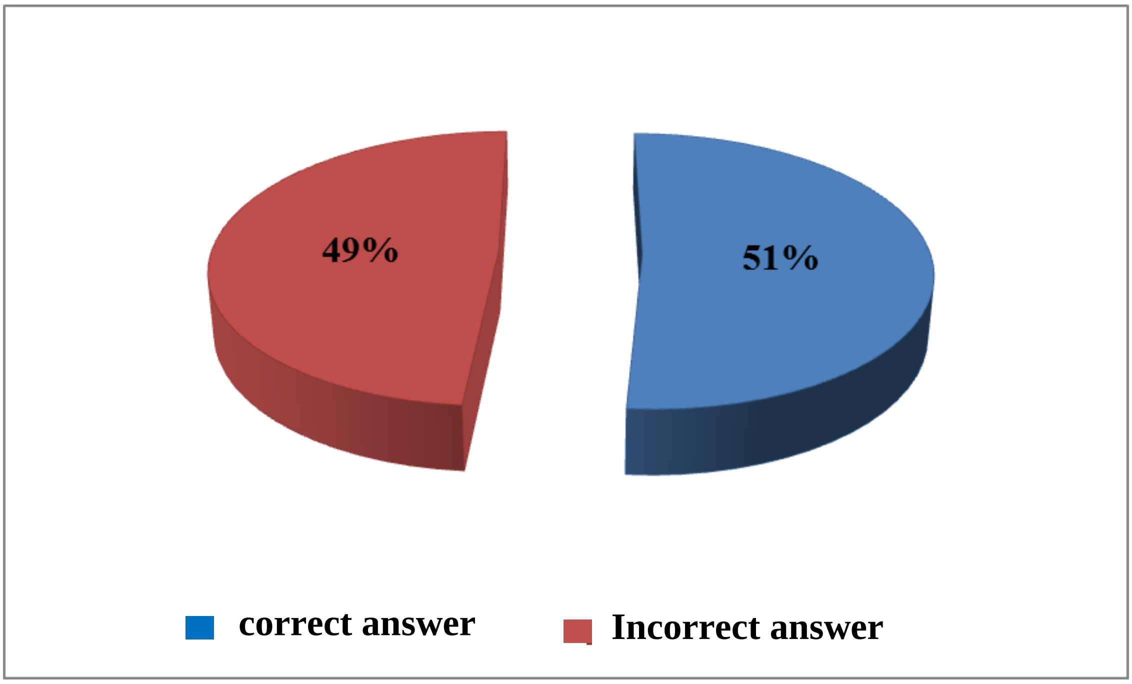

Figure 5.1: Total knowledge about readiness respiratory and hemodynamic toward WC from MV (N= 93)

5.3.2 Other screening readiness toward WC from MV

- ***Knowledge of nurses about other screening readiness toward WC from MV:***

Table 5.4 presents the knowledge of ICU nurses about other screening readiness to weaning from MV, while the majority of the nurses (81.7%) knew the Patient on spontaneously breathing should be stable condition, Whereas more than two third of the nurses (62.4%) knew the problem that causes the patient requires MV is still the problem, Also more than half of the nurses (51.6%) knew a weaning from long-term ventilation means Patient has tolerance two to three days weaning.

Table 5.4: Knowledge about other screening readiness toward WC from MV (N=93)

Statement	Responses			
	Correct answer		Incorrect answer	
	F	%	F	%
The problem that causes the patient requires MV must be?				
A. Resolved problem	45	48.4	48	51.6
B. Reduced the severity problem.	42	45.2	51	54.8
C. Still the problem.	**58**	**62.4**	35	37.6
D. Improve patient.	45	48.4	48	51.6
Patient on spontaneously breathing should?				
A. Stable condition.	**76**	**81.7**	17	18.3
B. None fatiguing.	47	50.5	46	49.5
C. Confortable from mechanical support.	55	59.1	38	40.9
D. Adequate cough and absence excessive secretion.	51	54.8	42	45.2
A weaning from long-term ventilation means.				
A. Patient in the mechanical ventilation > 72 hours.	47	50.5	46	49.5
B. Patient failed short-term weaning.	41	44.1	52	55.9
C. Patient require a period of regain strength of respiratory muscle.	39	41.9	54	58.1
D. Patient has tolerance two to three days weaning.	**48**	**51.6**	45	48.4

- ***Total knowledge about other screening readiness toward WC from MV:***

Regarding to the total knowledge about other screening readiness among ICU nurses was (53%) of the nurses had correct knowledge while (47%) of the nurses had incorrect knowledge. Figure 5.2.

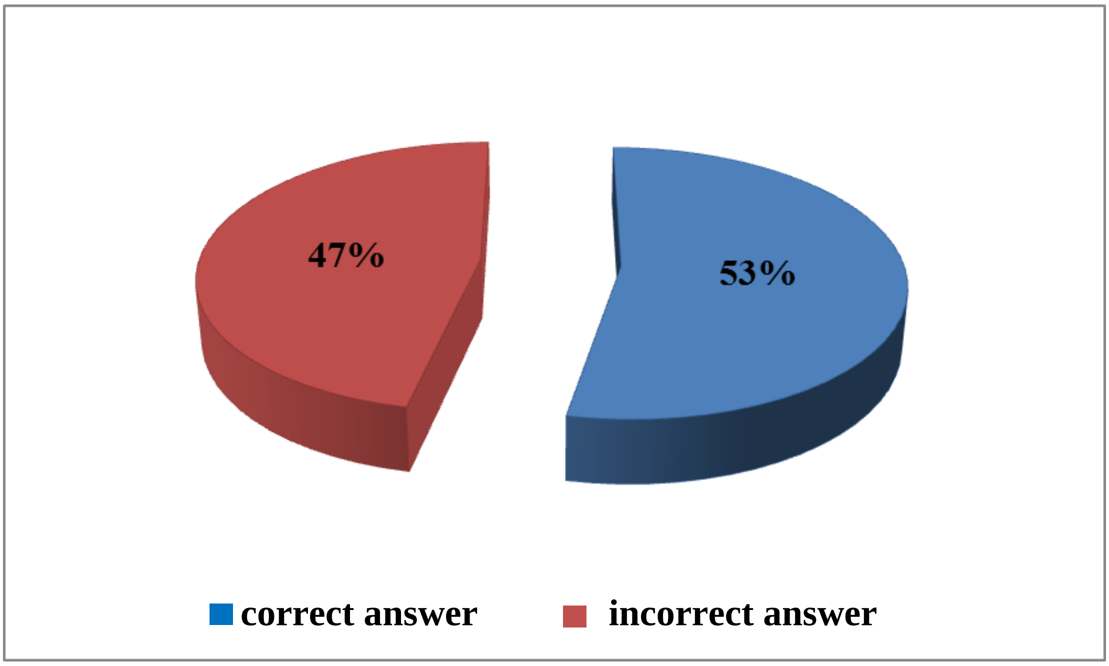

Figure 5.2: Total knowledge about other screening readiness toward WC from MV

5.3.3 Modes weaning intervention from MV

- ***Knowledge of nurses toward modes of weaning intervention from MV:***

More than two thirds of the nurses (69.9%) knew the mode of ventilator support patient need weaning were use pressure control mode. whereas (66.7%) of them knew the repeated weaning attempt on pressure support ventilation mode after rest period is occurs after 24 hours for all patient. Furthermore (57%) of them knew that during weaning the patient from mechanical ventilation you should converted from mode CMV to SIMV. Table 5.5.

Table 5.5: Knowledge of nurses toward modes of weaning intervention from MV (N= 93).

Statement	Responses			
	Correct answer		Incorrect answer	
	F	%	F	%
Which the mode ventilator support patient need weaning.				
A. Synchronized intermittent mandatory ventilation	53	57.0	40	43.0
B. Pressure support ventilation	42	45.2	51	54.8
C. Spontaneous breathing trial	48	51.6	45	48.4
D. Pressure control mode.	**65**	**69.9**	28	30.1
Repeat wean attempt on pressure support ventilation mode after rest period?				
A. After 24 h when long-term ventilation weaning.	41	44.1	52	55.9
B. A minimum after 2 hour.	40	43.0	53	57.0
C. Patient fails second weaning trial return to rest setting.	39	41.9	54	58.1
D. After 24 hours for all patient.	**62**	**66.7**	31	33.3
During weaning the patient from mechanical ventilation you should?				
A. Converted from mode CMV to SIMV.	**53**	**57.0**	40	43.0
B. Converted from mode SIMV to PS.	34	36.6	59	63.4
C. Converted from mode CMV to CPAP.	46	49.5	47	50.5
D. Converted from mode SP to CPAP.	46	49.5	47	50.5

- ***Total knowledge about modes of weaning intervention from MV:***

Figure 5.3 reveal the total knowledge of ICU nurses about modes of weaning intervention toward weaning criteria from MV, The findings of the study showed that (51%) of the nurses had correct knowledge and (49%) of them had incorrect knowledge.

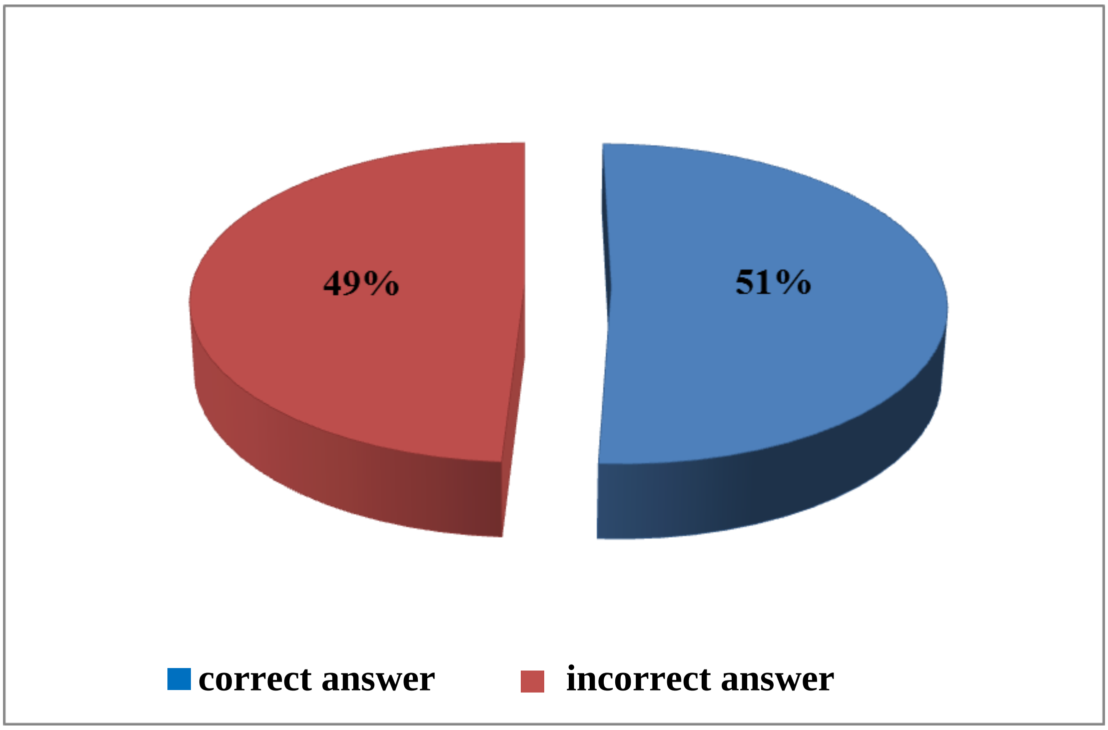

Figure 5.3: Total knowledge about modes of weaning intervention from MV

5.3.4 Recommendations parameters weaning intervention from MV

- ***Knowledge about recommendations parameters of weaning intervention from MV:***

The majority of the nurses (69.9%) knew the nursing care recommendation during weaning is keeping the patient in semi-sitting position 30-45 degree, While the most of the nurses (65.6%) knew the recommended time to check the ABG after 30 minutes of spontaneous breathing, Furthermore (52.7%) Of the nurses knew the correct recommendation parameter for weaning criteria is the vital capacity > 20 mL/kg. Table 5.6.

Table 5.6: Knowledge of nurses about recommendation parameters intervention from MV (N= 93).

Statement	Responses			
	Correct answer		Incorrect answer	
	F	%	F	%
A recommended time for assess the patient during weaning?				
A. ABG after 30 minutes of spontaneous breathing.	**61**	**65.6**	32	34.4
B. Vital signs every 15 minutes through one hour then routine for unit.	52	55.9	41	44.1
C. Spontaneously breathing trial 30 – 120 minute.	46	49.5	47	50.5
D. Continuous monitoring SPO_2.	56	60.2	37	39.8
A recommendation of nursing care during weaning is?				
A. Regular sterile suctioning.	56	60.2	37	39.8
B. Keeps the patient in semi sitting position 30- 45 degree.	**65**	**69.9**	28	30.1
C. Documentation weaning process.	46	49.5	47	50.5
D. Use a plan to regulate weaning.	41	44.1	52	55.9
The correct recommendation parameter for weaning criteria?				
A. Maximum inspiratory pressure > - 30 cm H_2O in 20 second.	32	34.4	61	65.6
B. The Minute ventilation < 10 L/minute.	34	36.6	59	63.4
C. Tidal volume spontaneously breathing > 5ml/kg.	45	48.4	48	51.6
D. Vital capacity > 20 mL/kg.	**49**	**52.7**	44	47.3

- ***Total Knowledge about recommendations parameters weaning intervention from MV:***

Figure 5.4 reveals the total knowledge of ICU nurses about recommendation parameters to weaning intervention from MV showed that (52%) of the nurses had correct knowledge and (48%) of them had incorrect knowledge.

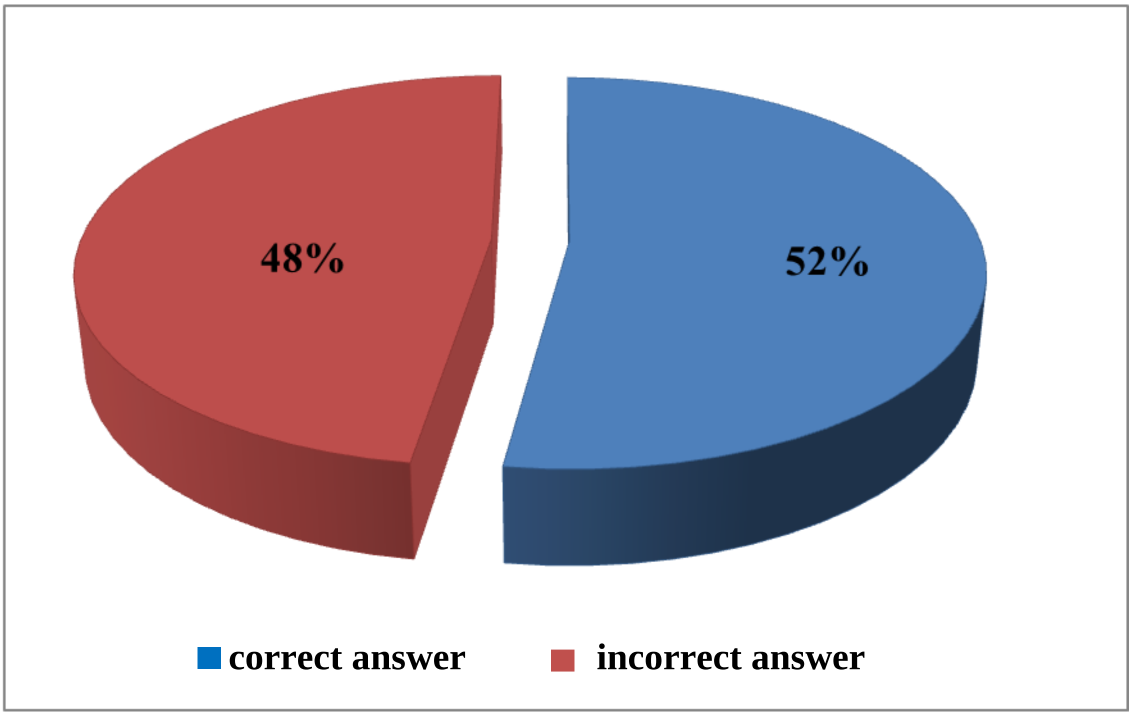

Figure 5.4: Total Knowledge about recommendation parameters weaning intervention from MV.

5.3.5 Tolerance criteria for WC from MV

- ***Knowledge of nurses about tolerance criteria for WC from MV:***

Table 5.7 shows the knowledge of ICU nurses about tolerance criteria for weaning from MV the findings of this study the majority of the nurses (74.2%) knew the best mode not fatiguing and comfortable patient after fail weaning is use T.peice, whereas more two third of the nurses (68.8%) Knew the failure of spontaneously breathing trial is use of accessory muscles and dyspnea, while the most of the nurses (67.7%) Knew failure hemodynamic stability tolerance weaning failure when the respiratory rate < 45 breath/min, also more than half of nurses (53.8%) knew the indicator for weaning failure is the tidal volume 5ml/kg or less,

Table 5.7: Knowledge of nurses about tolerance criteria for WC from MV (N= 93).

Statement	Correct answer		Incorrect answer	
	F	%	F	%
An indicator for weaning failure?				
A. Tidal volume 5m/kg or less.	**50**	**53.8**	**43**	46.2
B. $PaCO_2$ > 50 mmHg.	38	40.9	55	59.1
C. SaO_2 less than 90%.	49	52.7	44	47.3
D. Increased RR > 35 breath/minute.	46	49.5	47	50.5
Failure of spontaneously breathing trial?				
A. Use of accessory muscles.	**64**	**68.8**	29	31.2
B. Dyspnea.	**64**	**68.8**	29	31.2
C. Hypoxemia.	52	55.9	41	44.1
D. Diaphoresis.	47	50.5	46	49.5
Failure hemodynamic stability tolerance weaning failure is?				
A. Systolic blood pressure < 90 - > 180 mmHg.	59	63.4	34	36.6
B. Temperature < 36 - > 39 C◦.	38	40.9	55	59.1
C. Heart rate > 140 beat/minute.	51	54.8	42	45.2
D. Respiratory rate < 45 breath/min.	**63**	**67.7**	30	32.3
Which is the best mode not fatiguing and comfortable patient after fail weaning?				
A. CPAP.	56	60.2	37	39.8
B. SIMV.	61	65.6	32	34.4
C. PSV.	68	73.1	25	26.9
D. T. peice.	**69**	**74.2**	24	25.8

- ***Total knowledge about tolerance criteria for WC from MV:***

Figure 5.5 presents the total knowledge of ICU nurses about tolerance criteria for weaning criteria from MV. The findings of the study showed that (59%) of the nurses had correct knowledge, while (41%) of them had incorrect knowledge.

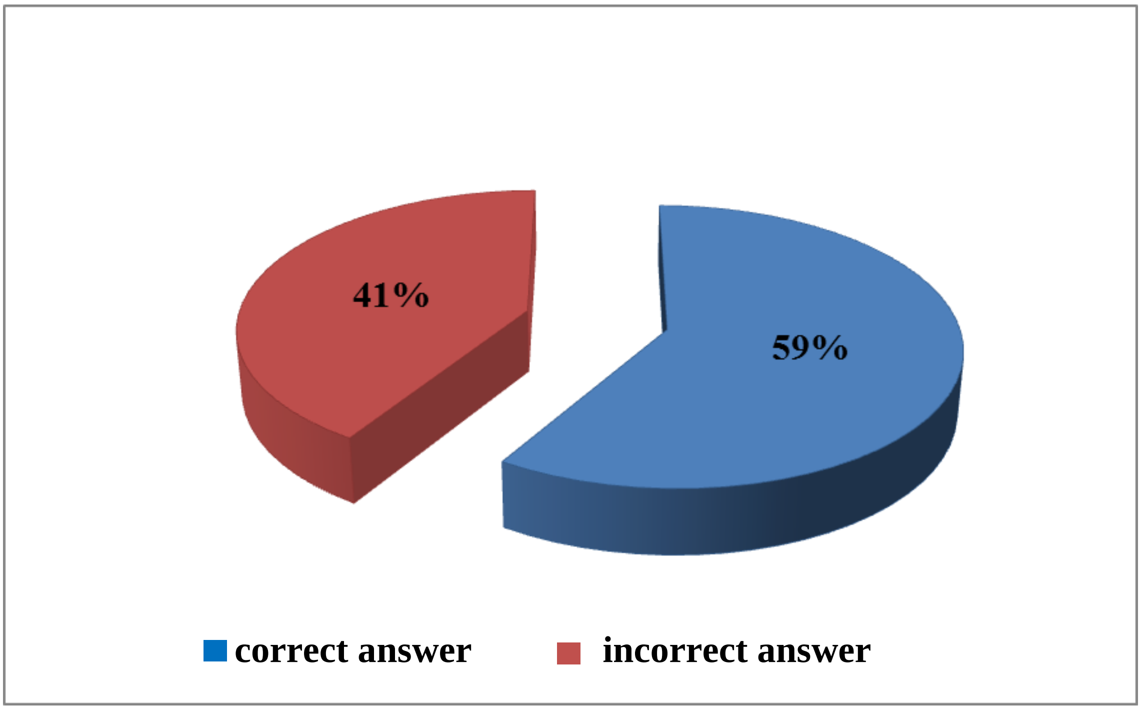

Figure 5.5: Total knowledge about tolerance criteria for WC from MV (N= 93)

5.3.6 Extubation toward WC from MV

- ***Knowledge about extubation toward WC from MV:***

The results of the study on knowledge of ICU nurses related to an extubation showed that anesthesia/sedation strategies & ventilator management that aimed to early extubation should be used after weak of patient stay in ICU (75.3%), while more than two third of the nurses (69.9%) Knew an extubation criteria is airway patency. Whereas the Parameter for extubation criteria is RR 13-<30 breath/minute and SaO_2>94% on FIO_2 40% (61.3%), More details presenting in table 5.8.

Table 5.8: Knowledge of nurses about extubation criteria toward WC from MV (N= 93)

Statement	Correct answer		Incorrect answer	
	F	%	F	%
A extubation criteria is?				
A. The patient less secretion.	54	58.1	39	41.9
B. Airway patency.	**65**	**69.9**	28	30.1
C. Patient able to protection airway.	47	50.5	46	49.5
D. GCS > 8.	40	43.0	53	57.0
Parameter for extubation criteria?				
A. RR 13 - < 30 breath/minute.	**57**	**61.3**	36	38.7
B. VT > 5 mL/kg.	50	53.8	43	46.2
C. SaO_2 > 94% on FIO_2 .40%.	**57**	**61.3**	36	38.7
D. Vital capacity > 15 mL/kg.	47	50.5	46	49.5
Anesthesia/sedation strategies & ventilator management that aimed to early extubation should be used at				
A. Post-surgical patient.	53	57.0	40	43.0
B. During stay in ICU.	49	52.7	44	47.3
C. After weak for patient stay in ICU.	**70**	**75.3**	23	24.7
D. For the patient irreversible diseases.	63	67.7	30	32.3

- ***Total knowledge about extubation toward WC from MV:***

Figure 5.6 presents the total knowledge about extubation toward weaning criteria from MV, The results of the study showed that (58%) of the nurses had correct knowledge and (42%) of them had incorrect knowledge.

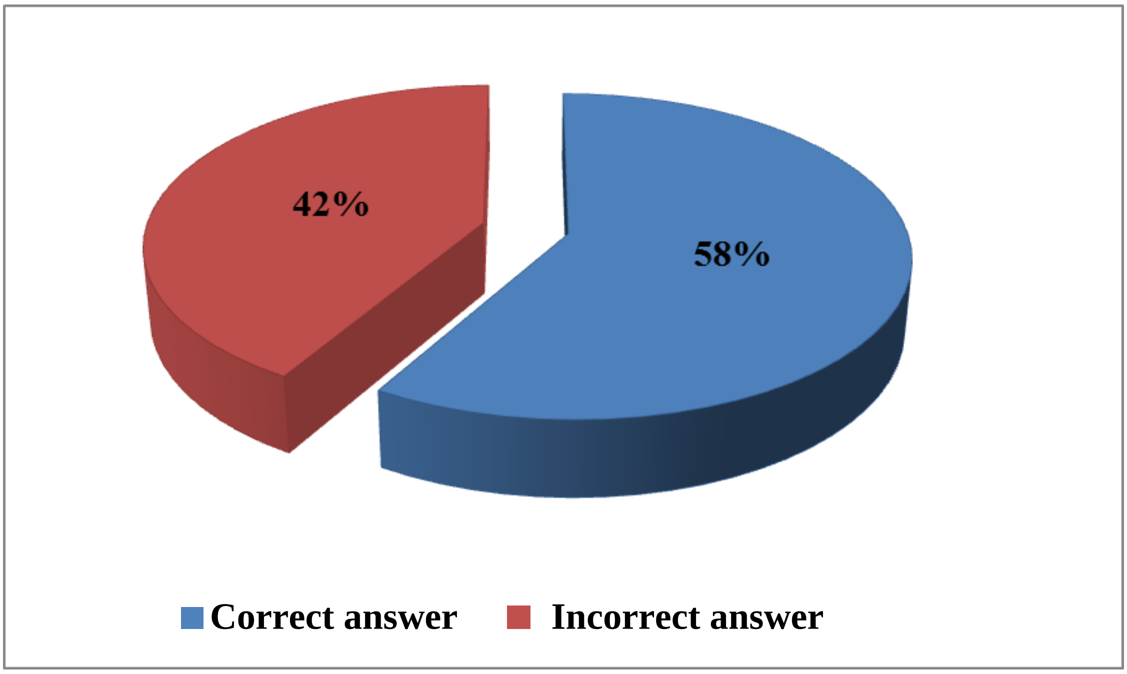

Figure 5.6: Total knowledge about extubation toward WC from MV (N= 93).

5.4 Overall knowledge toward weaning criteria from MV

As regards to the overall knowledge of ICU nurses toward weaning criteria from MV showed that (54%) of the nurses had correct knowledge toward weaning criteria from MV, whereas (46%) of them had incorrect knowledge. Figure 5.7.

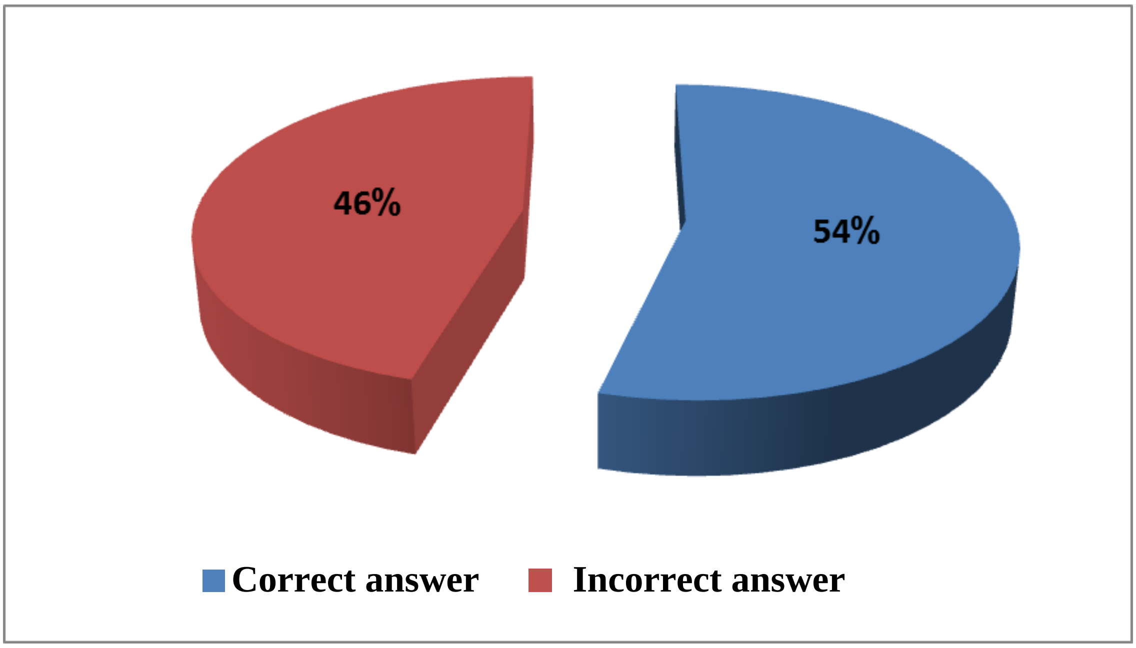

Figure 5.7: Overall knowledge of nurses toward weaning criteria from MV (N= 93)

5.5 Level of knowledge about weaning criteria from MV

Figure 5.8 shows the level of knowledge among nurses toward the weaning criteria from MV. The findings of the study showed that (39%) of the nurses had poor level of knowledge, whereas (50%) of the nurses had moderate level of knowledge, And (11%) of the nurses had good level of knowledge.

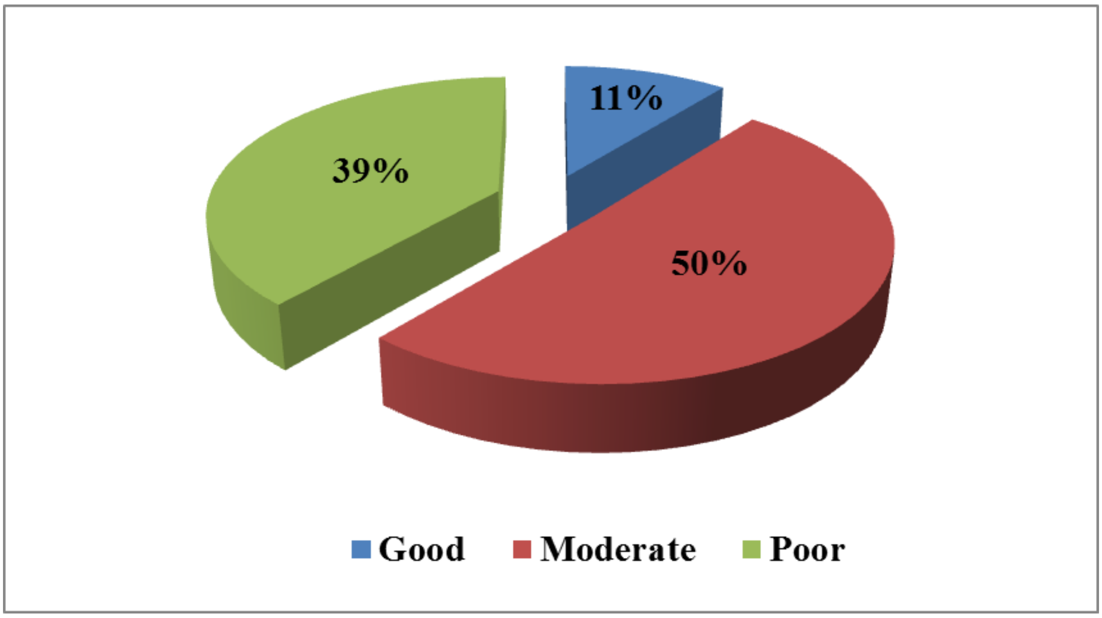

Figure 5.8: Level of knowledge among nurses toward WC from MV (N= 93)

5.6 Overall knowledge scores by demographic characteristics of nurses

Table 5.9 presents the relationship between the demographic characteristics and the overall knowledge scores toward weaning criteria from MV. The result showed that there was no statistically significant differences between the mean knowledge scores toward weaning criteria from MV and all demographic characteristics the (P-value >0.05),

Table 5.9: Overall knowledge scores toward WC from MV by demographic characteristics of nurses (N= 93)

Demographic characteristics	Total knowledge scores Mean ± SD	p-value
Age group		0.235**
• 20- 30	43.1±13.1	
• 31- 40	44.9±12.5	
• >40	29±1.4	
Sex		0.307*
• Male	42.1±12.3	
• Female	44.8 ± 13.6	
Marital status		0.072*
• Single	40.7±13.1	
• Married	45.6 ± 12.5	
Educational level		0.682**
• Diploma degree	43.7 ± 13.7	
• Bachelor degree	42.1±11.2	
• Master degree	47.7±14.3	
Work experiences		0.705**
• 1 to 5 years	43.98±13.3	
• 6 to 10 years	42.25±10.6	
• ≥10 years	40.14±15.6	

t-test; **One way ANOVA

5.7 Association between level of knowledge toward WC from MV and workplace

Table 5.10 shows the relationship between the level of knowledge toward weaning criteria from MV and workplace. There was no a statistically significant the relationship between the level of knowledge toward weaning criteria from MV and hospital name and type of ICU (P-value= 0.180 and 0.063) respectively.

Table 5.10: Association between level of knowledge toward WC from MV and workplace of nurses (N= 93)

Workplace	Level of knowledge			p-value*
	Good	Moderate	Poor	
Hospital Name				0.180
• Al-Thowrah hospital	4	26	14	
• Al-Jomhury hospital	4	5	10	
• Al-Kuwait hospital	0	10	6	
• Al-Sabeen hospital	2	6	6	
Type of ICU				0.063
• General ICU	1	11	14	
• Pediatric ICU	0	8	7	
• Emergency ICU	1	6	6	
• Surgical ICU	1	5	1	
• Medical ICU	1	9	3	
• Other (Neuro, nephron and cardio)	10	47	36	

x^2 -test

5.8 Overall knowledge scores toward WC from MV by training among nurses

Table 5.11 presents the differences in the overall knowledge scores toward weaning criteria from MV and training among nurses. There was statistical significant differences between the mean knowledge scores toward weaning criteria from MV and diploma degree in respiratory therapy (P-value=0.004) while there was no statistically significant differences in mean knowledge scores toward weaning criteria from MV by course training in ICU and course training in weaning criteria (P-value= 0.309 and 0.086) respectively.

Table 5.11: Differences in mean knowledge scores toward WC from MV by training among nurses (N=93)

Training	Overall score toward WCFMV		p-value*
	Yes	No	
Courses training in ICU			
• Mean ± SD	45.1 ± 14.1	42.3 ± 12.2	0.309*
Course training in weaning criteria			
• Mean ± SD	43.1± 15.9	43.5 ± 12.4	0.086*
Diploma in respiratory therapy			
• Mean ± SD	51.8± 8.8	41.6± 12.7	**0.004***

t-test

5.9 The practices of ICU nurses toward WC from MV.

5.9.1 Readiness weaning toward WC from MV

- ***Practice about readiness weaning toward WC from MV:***

Regards to the practice of ICU nurses about the readiness for weaning from MV, while the majority of the nurses (93.5%) putting the patient in semi-sitting position, while most of the nurses (83.9%) decreased FIO_2 40% or less, PEEP 5 cm H_2O or less, whereas most of the nurses (79.6%) stopped giving sedation and muscle relaxants drug, and more than the half of the nurses (61.3%) applied mouth care and oral suctioning prior to starting weaning trial, about one third of them (35.5%) applied hands washing before and after oral care, tracheal suction, touch patient or equipment and applied chest physiotherapy, while (22.6%) of the nurses assessed hemodynamic stability, or used low dose vasoactive support, About (9.7%) of the nurses assessed spontaneous breathing trial according criteria, moreover (9.7%) of the nurses assessed the adequate management of pain/anxiety/agitation. Table 5.12.

Table 5.12: Practice of nurses about readiness weaning toward WC from MV (N= 93)

Practice	Response					
	Done		Need correct		Not done	
	F	%	F	%	F	%
1. Decrease $FIO_2$40% or less, PEEP 5cm H_2O or less.	78	83.9	7	7.5	8	8.6
2. Assessment spontaneously breathing trial according criteria.	9	9.7	19	20.4	65	69.9
3. Assess hemodynamic stability, or with low dose vasoactive support	21	22.6	12	12.9	60	64.5
4. Assess the adequate management of pain/anxiety/agitation.	9	9.7	8	8.6	76	81.7
5. Stop sedation and muscle relaxants drug.	74	79.6	0	0.0	19	20.4
6. Mouth care and oral suctioning prior to starting weaning trial.	57	61.3	7	7.5	29	31.2
7. Apply hands washing before and after oral care, tracheal suction, touch patient or equipment.	33	35.5	14	15.1	46	49.5
8. Putting the patient in semi-sitting position at (30˚ to 45˚).	87	93.5	3	3.2	3	3.2
9. Apply chest physiotherapy.	33	35.5	16	17.2	44	47.3

- ***Total Practice about readiness weaning toward WC from MV:***

The result showed that the nurses who applied these criteria composed 45% of the total ICU nurses, on the other hand nurses who do these but need correction constituted 10 %, moreover of the nurses did not perform 45%. Figure 5.9**.**

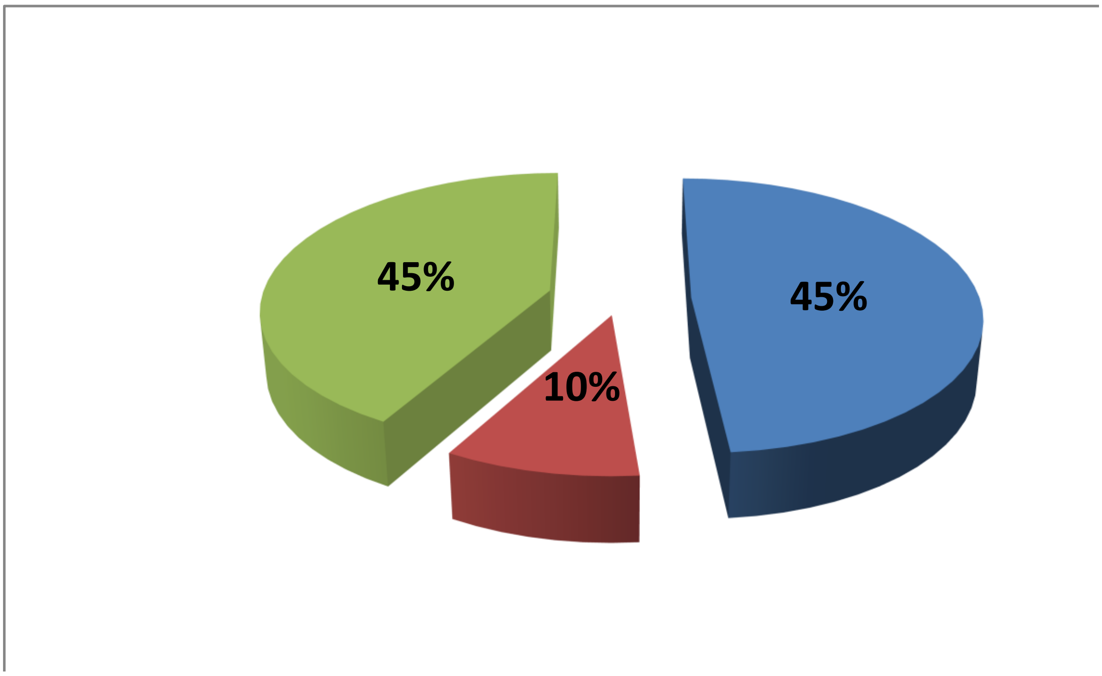

Figure 5.9: Total practice about readiness of weaning toward WC from MV (N= 93)

5.9.2 Weaning intervention from MV

- ***Practice of ICU nurses toward weaning intervention from MV:***

Table 5.13 shows the practice of ICU nurses about weaning intervention from MV. The majority of the nurses (87.1%) discontinued MV and connect patient to T-pace tube, while the most of the nurses (78.5%) decreased FiO_2, whereas more than half of the nurses (58.1%) Gradually decreased mandatory breathing**,** about one third of the nurses (35.5%) convert to pressure-support ventilation (PSV), about one quarter of the nurses (24.7%) decreased the PSV as tolerated to 10 cm H_2O or less, the fifth (20.4%) of them checked the ABGs and adjust MV according to results, and (14.0%) of the nurses assessed the patient for extubation criteria, moreover of the nurses (9.7%) who assessed the patient for tolerance criteria for at least 2 hours,.

Table 5.13: Practice of ICU nurses toward weaning intervention (N= 93)

Items	Response					
	Done		Need correct		Not done	
	F	%	F	%	F	%
1. Gradually decreasing mandatory breathing.	54	58.1	8	8.6	31	33.3
2. Gradually decrease FiO_2.	73	78.5	5	5.4	15	16.1
3. Convert to pressure-support ventilation (PSV).	33	35.5	4	4.3	56	60.2
4. Decrease the PSV as tolerated to 10 cm H_2O or less	23	24.7	9	9.7	61	65.6
5. Assess the patient for tolerance criteria for at least 2 hours.	9	9.7	22	23.7	62	66.7
6. Check the ABGs and adjust MV according to results.	19	20.4	16	17.2	58	62.4
7. Discontinued MV and connect patient to T-pace.	81	87.1	5	5.4	7	7.5
8. Assess the patient for extubation criteria	13	14.0	15	16.1	65	69.9

- ***Total practice of ICU nurses toward weaning intervention from MV:***

The total practice about the weaning intervention from MV showed in this result the nurses that applied these criteria composed (41%) of the total ICU nurses, and on the other hand nurses who do these but need correction constituted (11%) moreover the nurses did not performed (48%). Figure 5.10.

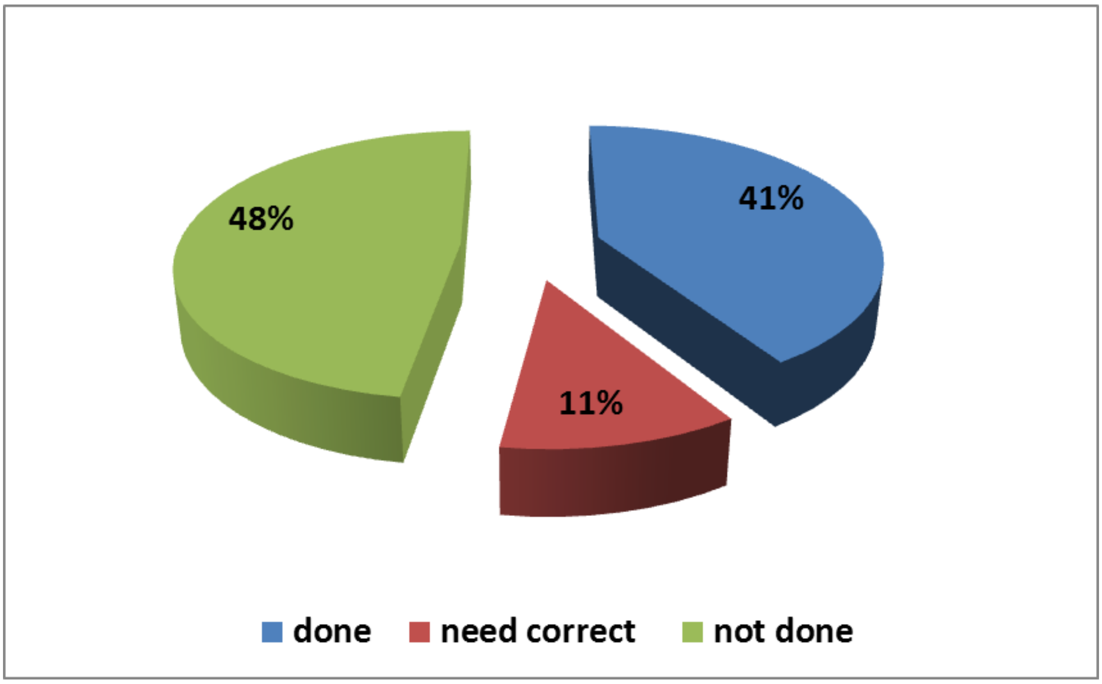

Figure 5.10: Total practice of nurses toward weaning intervention (N= 93).

5.9.3 Extubation

- ***Practice of ICU nurses toward extubation***

Table 5.14 shows the practice of ICU nurses toward equipment for extubation. The results of the study showed most of the nurses (93.5%) keeping patient in upright sitting position and placed patient on supplemental oxygen afterward, also performed oral and ETT suction (90.3%), While more than half of the nurses (54.8%) deflated ETT cuff, Whereas (36.6%) of them smoothly take out the ETT and (23.7%) of them applied Suction the oral cavity and asked patient to cough, While the fifth of them (20.4%) documented weaning process, and (19.4%) of them encourage patient to take deep breathing, The nurses who prepare all necessary equipment for extubation and re-intubation composed only (7.5%) More details presenting in table 5.14.

Table 5.14: Practice of ICU nurses toward extubation (N= 93).

Items	Response					
	Done		Need Correct		Not done	
	F	%	F	%	F	%
1. Prepare all necessary equipment for extubation and re-intubation.	7	7.5	11	11.8	75	80.6
2. Putting patient in upright sitting position.	87	93.5	1	1.1	5	5.4
3. Oral and ETT suction.	84	90.3	0	0.0	9	9.7
4. Deflate ETT cuff.	51	54.8	12	12.9	30	32.3
5. Encourage patient to take deep breathing.	18	19.4	12	12.9	63	67.7
6. Smoothly take out ETT.	34	36.6	5	5.4	54	58.1
7. Suction the oral cavity and ask patient to cough.	22	23.7	16	17.2	55	59.1
8. Placed patient on supplemental oxygen afterward.	87	93.5	3	3.2	3	3.2
9. Documentation before, during, after weaning process.	19	20.4	19	20.4	55	59.1

- ***Total practice of ICU nurses toward extubation***

The figure five showed less than half (49%) of ICU nurses performed correct practices extubation toward weaning criteria from MV, and (42%) of them didn't performed, while (9%) of them do these but need correction practices. Figure 5.11.

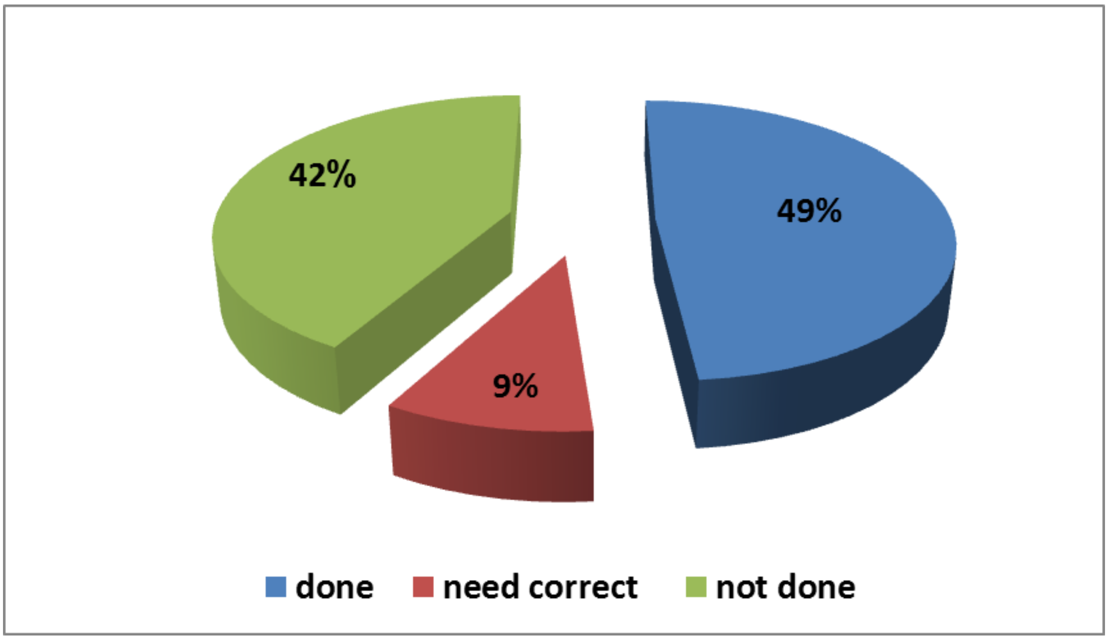

Figure 5.11: Total practice of nurses toward extubation (N= 93).

5.10 Overall practice of ICU nurses toward WC from MV

Figure 5.12 describes the overall practice of ICU nurses toward weaning criteria from MV. The findings of this study showed that less than half of the nurses (46%) correctly practiced, whereas (44%) of the nurses didn't performed, on the other hand the nurses who do these but need correction practices (10%).

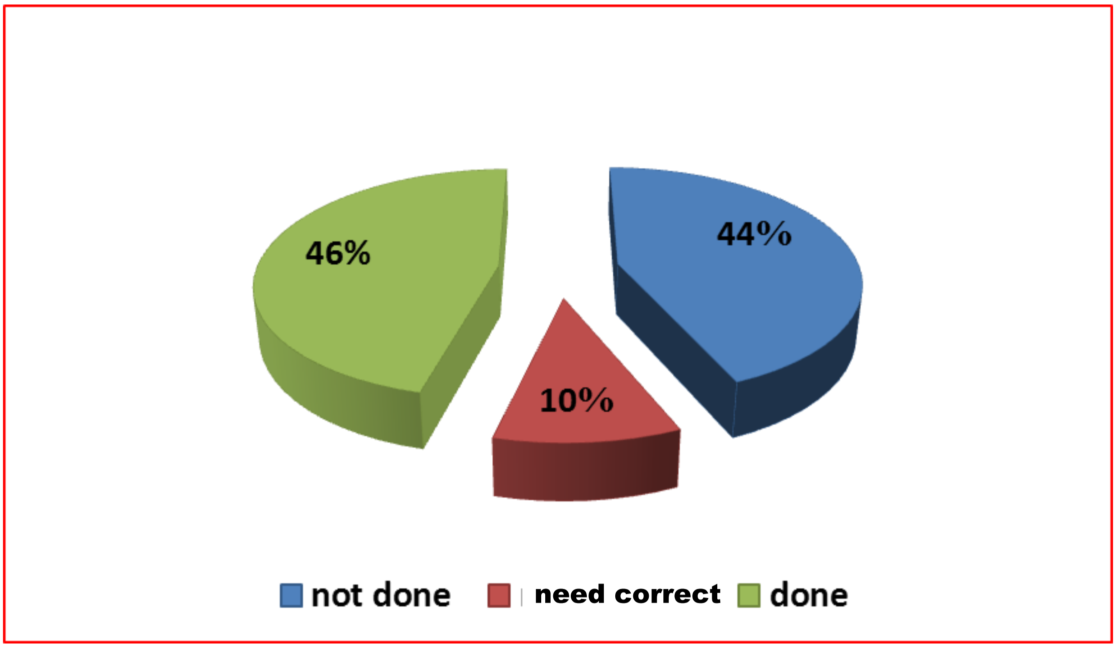

Figure 5.12: Overall practice toward WC from MV among nurses (N= 93)

5.11 Level of practice among ICU nurses toward WC from MV

Figure 5.13 reveals that the level of practice toward weaning criteria from MV among nurses. There was (49%) of the nurses had poor level of practices toward weaning criteria from MV. Whereas (36%) of them had a moderate level of practices and (15%) of them had a good level of practices.

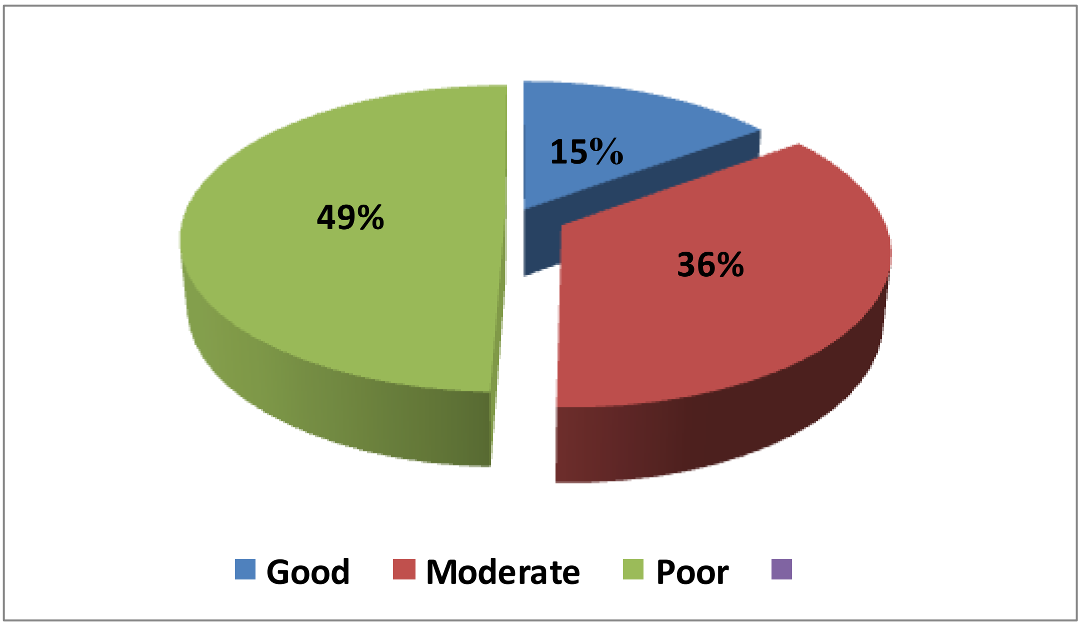

Figure 5.13: Level of practice among nurses toward WC from MV (N= 93).

5.12 Overall practice scores in relation to demographic characteristics of nurses

There is statistically significant differences was found in mean practice scores by age (P-value=0.004). Furthermore there was a significant differences in mean practice scores by marital status of nurses (P-value=0.031), level of educational (P-value=0.016) and work experiences (P-value=0.048). While there was no statistically significant differences in mean practice scores toward weaning criteria from MV by sex (P-value=0.554). Table 5.15.

Table 5.15: Differences in mean practices scores toward WC from MV by nurses training (N= 93)

Demographic characteristics	Overall practices toward WCFMV **Mean** ± SD	p-value
Age group		**0.002****
• 20- 30	24.5±8.6	
• 31- 40	31.1± 9.16	
• >40	26±8.5	
Sex		0.554*
• Male	26.1 ±9.3	
• Female	27.2 ± 9.2	
Marital status		**0.031***
• Single	24.4 ±9.7	
• Married	28.6 ± 8.4	
Educational level		**0.016****
• Diploma degree	24.8±8.5	
• Bachelor degree	29.4±9.8	
• Master degree	34.7±8.1	
Work experiences		**0.048****
• 1 to 5 years	25.6±9.3	
• 6 to 10 years	27.7±7.9	
• ≥10 years	34.1±9.0	

t-test; **One way ANOVA

5.13 Overall practice scores by nurses training

Table 5.16 shows a statistically significant differences in the mean practice scores toward weaning criteria from MV by course training in ICU (P-value=0.033). while there is statistically significant differences in mean practice scores by course training in weaning criteria was found (P-value= 0.034) Furthermore there is statistically significant differences in mean practice scores by diploma in respiratory therapy (P-value= 0.026).

Table 5.16: Differences in mean practice scores toward WC from MV by nurses training

Training	Overall score toward WCFMV		p-value*
	Yes	No	
Courses training in ICU			
• Mean ± SD	29.1 ± 10.29	24.96 ± 8.1	0.033
Course training in weaning criteria			
• Mean ± SD	31.26± 10.1	25.76 ± 8.85	0.034
Diploma in respiratory therapy			
• Mean ± SD	31.31± 8.11	25.68 ± 9.1	0.026

t-test

5.14 Association between level of practice and workplace toward WC from MV

Table 5.17 shows the association between level of practice toward weaning criteria from MV and workplace of nurses, There is statistically significant association between level of practice toward weaning criteria from MV and hospital name was found (P-value= 0.009), on other hand a statistically significant association between level of practice toward weaning criteria from MV and type of ICU was observed (P-value= 0.04).

Table 5.17: Association between level of practice toward WC from MV and workplace

Workplace	Level of practices			p-value*
	Good	Moderate	Poor	
Hospital Name				
• Al-Thowrah hospital	11	17	16	**0.009**
• Al-Jomhury hospital	2	10	7	
• Al-Kuwait hospital	1	2	13	
• Al-Sabeen hospital	0	4	10	
Type of ICU				
• General ICU	1	9	16	**0.04**
• Pediatric ICU	2	3	10	
• Emergency ICU	2	4	7	
• Surgical ICU	4	3	0	
• Medical ICU	1	6	6	
• Other (Neuro, nephron and cardio)	4	8	7	

x^2- test

CHAPTER SIX: DISCUSSION

6.1 Introduction

The intensive care unit is the most suitable place to care for critically ill adults and children under MV ***(Tang W., et al, 2012).*** Nurses who are caring for patients supported with MV require special technical skills. Nurses must be equipped with basic information of ventilator settings, with expertise in monitoring and highly competent in assessing safety of patient and complication prevention ***(Grossbach et al , 2011)***. So the current study objective was to assess of knowledge and practice levels of ICU nurses toward weaning criteria from MV at public hospitals in Sana'a city Yemen. The results of this study were based on the primary data gathered from ninety-three ICU nurses. The weaning criteria from mechanical ventilation it is from responsibility of the nurse whose knowledge and practice influence the health outcome of ICU patients. Critical care nurses play a significant role in the weaning process from mechanical ventilation.

This chapter presents the major findings of the study and discusses them in relation to similar studies conducted by other researchers; this helped the researcher to prove that the findings were true about knowledge and practice.

6.2 Demographical characteristics of ICU nurses

Ninety-three ICU nurses were recruited and all completed the questionnaire, about (51.6%) of ICU nurses were males. The mean age± SD, 29.7± 4.5 years with (65.6%) aged ranged from 20-30 years. (64.5%) had a diploma in nursing, less than half of ICU nurses (40.9%) had courses training in ICU and the majority of nurses (83.9%) had not received on training weaning criteria from MV, and (70%) were working in ICU for 1-5 years. The findings of the present study agreed with the study conducted in university of norway by ***Haugdahl (2016)***, also our results are in an agreement with the study conducted by ***Mamta Thapa (2013)***, (61.4%) had qualification diploma degree in nursing and (78.9%) working in general intensive care unit.

This results were disagreement with results reported by ***Nathan woody (2013).*** A study to assess the knowledge regarding weaning the critically ill patient from MV among ICU nurses at selected hospital in Bangalore, (80%) had no training program on the weaning criteria from MV.

6.3 Knowledge of nurses about WC from MV

The present study also contributed to the knowledge and understanding the weaning criteria from MV and explored staff perceptions of the effect of weaning criteria had on their specific and general practice influence the health outcome of ICU patients; Critical care nurses play very important role for successful weaning from MV***(Nahla et al, 2018).***

All nurses in the study attained 7 main concepts descriptive of the "weanable" patient. They collected objective physiological cues of gas exchange, work of breathing, resolving lung condition and level of consciousness and subjective criteria of patients' tolerance and response to previous reduction of ventilatory support to inform their decisions, assessment of the patient and make the diagnosis of a "weanable" patient. The objective physiological criteria that nurses referred to in their thinking are part of the international guidelines for weaning mechanical ventilation ***(MacIntyre 2013; Kydonaki et al, 2016).***

- ***Knowledge about respiratory and hemodynamic readiness weaning from MV:***

Regarding to knowledge about readiness weaning from MV, the results about knowledge screening respiratory and hemodynamic toward weaning criteria was found in (51%) of the nurses had correct answer on assess the respiratory and hemodynamic stable for readiness weaning criteria from MV. This finding disagreed with the study was conducted in Copenhagen the capital of Denmark ***(Egerod, 2003)***. Knowledge and practice of intensive care nurses towards weaning criteria from mechanical ventilation who found that the majority (80.2%) of ICU nurses had correct answer on assess the respiratory and hemodynamic stable for readiness weaning criteria from MV.

- ***Knowledge of nurses about others screening readiness weaning from MV:***

Regards to the knowledge of ICU nurses about other screening readiness toward weaning criteria from MV while the majority of nurses (81.7%) know the patient on spontaneously breathing should be in stable condition, Whereas (51.6%) of them knew a weaning from long-term ventilation means that style the patient in the MV > 72 hours, Whereas more than two third of the nurses (62.4%) know the problem that causes the patient requires MV is still the problem.

The results of this study approximately was similar to a study conducted by ***Haugdahl (2016)*** since (78.6%) of the nurses knew that the patient on spontaneous breathing should be in stable condition, whereas about (50.2%) of them knew that weaning from long-term ventilation is occurs when the patient with MV more than 72 hours, Whereas more than two third of the nurses (59.6%) knew the problem that causes the patient requires MV is still the problem.

- ***Total knowledge about other screening readiness toward WC from MV:***

  This study showed that the total knowledge about other screening readiness among ICU nurses was (53%) of the nurses had correct knowledge while (47%) had incorrect knowledge.

  The results of this study approximately was similar to a study conducted by ***Haugdahl (2016)*** since the total knowledge about other screening readiness among ICU nurses was (54%) of the nurses had correct knowledge while (48%) had incorrect knowledge.

- ***Knowledge of ICU nurses about modes of weaning intervention from MV:***

This study showed that more than two third of the nurses (69.9%) knew that the mode of ventilator support patient need for weaning using pressure control mode, whereas (66.7%) knew that the repeated weaning attempt on pressure support ventilation mode after rest period is not occurs after 24 hours for all patient. Furthermore more than of the nurses (57.0%) Knew during weaning patient from mechanical ventilation the patient should be converted from mode CMV to SIMV.

This finding disagrees with the study conducted in USA ***(Fernandez, 2010)*** Methods of weaning Patients from Mechanical Ventilation (50.3%) of nurses knew mode ventilator support patient need weaning were use Pressure control mode, whereas (80.1%) of them knew that the repeated weaning attempt on pressure support ventilation mode after rest period is not occurs after 24 hours for prolonged weaning from MV.

Also This finding is supported by a study conducted in Madrid, Spain by ***Frutos-vivar (2017)*** wean from a ventilator: An evidence-based strategy(75.9 %) of the nurses during weaning the patient from mechanical ventilation you should converted from mode CMV to SIMV.

- ***Total knowledge about modes of weaning intervention from MV:***

This study showed that the total knowledge of ICU nurses about modes of weaning intervention toward weaning criteria from MV, The findings of the study showed that (51%) of the nurses had correct knowledge and (49%) had incorrect knowledge.

This finding disagrees with the study conducted in USA ***(Fernandez, 2010)*** the total knowledge of ICU nurses about modes of weaning intervention toward weaning criteria from MV, whereas (57%) of the nurses had correct knowledge and (43%) of them had incorrect knowledge.

- ***Knowledge of nurses about recommendation parameters weaning intervention from MV:***

This study shows that more than half of nurses (65.6%) know the correct recommendation parameter for weaning criteria is check the ABG after 30 minutes of spontaneous breathing. Whereas (69.9%) of them knew the correct recommendation nursing care during weaning is keeps the patient in semi- sitting position 30-45 degree, while (52.7%) of them knew the correct recommendation parameter for weaning criteria it is occurs when the vital capacity > 10 mL/kg.

Our study findings are agreed with the study conducted by ***Blackwood et al., (2011)*** he found that more than half nurses (54.2%) knew that check the ABG after 30 minutes of spontaneously breathing, finding disagrees with study was conducted in London to assess knowledge, practice toward weaning criteria from MV ***(Blackwood and Wilson-barnett, 2007).*** The findings of this study showed that less than half of the nurses (42.6%) knew that keeps the patient in semi- sitting position 30-45 degree, while (65%) of them knew the correct recommendation parameter for weaning criteria is occurs when the vital capacity > 10 mL/kg.

- ***Total Knowledge about recommendations parameters weaning intervention from MV:***

This study showed the total knowledge of ICU nurses about recommendation parameters to weaning intervention from MV showed that (52%) of the nurses had correct knowledge and (48%) had incorrect knowledge.

The results of this study approximately was similar to a study in Madrid, Spain by ***Frutos-vivar (2017)*** wean from a ventilator: An evidence-based strategy the total knowledge of ICU nurses about recommendation parameters to weaning intervention from MV showed that (51.3%) of the nurses had correct knowledge and (49.7%) had incorrect knowledge.

- ***Knowledge of nurses about tolerance criteria for weaning criteria from MV:***

This ours study showed that more than half of nurses (53.8%) knew the indicator for weaning failure is the tidal volume 5ml/kg or less, also the failure of spontaneous breathing trial (68.8%) of them knew is use of accessory muscles and dyspnea, whereas (67.7%) of nurses knew failure hemodynamic stability tolerance weaning failure when the respiratory rate more ≥45 breath/min, whereas (73.1%) of them knew which is the best mode not fatiguing and comfortable patient after fail weaning it is use SIMV mode.

This finding is agreed with the study was conducted in Muncie, Indiana on the Knowledge of ICU nurses about tolerance criteria for weaning criteria from MV***(Carter, 2012)*** who found that (74%) of ICU nurses know the indicator for weaning failure is the tidal volume 5ml/kg or less, whereas the majority of nurses (83%) knew the failure of spontaneously breathing trial is use of the accessory muscles and dyspnea.

This finding disagrees with the study was conducted in Gothenburg, Sweden by ***Niraj Niranjan (2018).*** Reporter that (57.4%) of ICU nurses knew failure hemodynamic stability tolerance weaning failure when the respiratory rate more ≥45 breath/min, whereas (66%) of ICU nurses knew the best mode not fatiguing and comfortable patient after failure weaning is use SIMV mode.

- ***Total knowledge about tolerance criteria for WC from MV:***

In the light of the current study results the total knowledge of ICU nurses about tolerance criteria for weaning criteria from MV, The findings of the study showed that (59%) of the nurses had correct knowledge, while (41%) of them had incorrect knowledge.

***Pradhan and Shrestha,* (2017)** who study nurses' knowledge regarding weaning criteria of the patients with mechanical ventilation in a teaching hospital, Chitwan, found total knowledge of ICU nurses about tolerance criteria for WC from MV, More than half of the nurses (52%) had correct knowledge, while (48%) of them had incorrect knowledge.

- ***Knowledge of nurses about extubation toward weaning criteria from MV:***

The present study showed the that the knowledge of nurses related to a extubation criteria & parameter for extubation criteria and sedation strategies & ventilator management for early extubation (69.9%) know an extubation criteria is airway patency, whereas the parameter for extubation criteria is RR 13 - < 30 breath/minute and SaO_2 > 94% on FIO_2 40% (61.3%) and anesthesia/sedation strategies & ventilator management that aimed to early extubation should use after post-surgical (75.3%).

This findings disagrees with the study was conducted in Qatar, Arab by ***Colgan, & Imfma, & Malmstrom (2015),*** they reported that (58.9%) of the nurses were know an extubation criteria is airway patency and anesthesia/sedation strategies & ventilator management that aimed to early extubation should use post-surgical (80.3%). But agrees in regards to the parameter for extubation criteria is RR 13 - < 30 breath/minute and SaO_2 > 94% on FIO_2 40% (60.3%).

- ***Total knowledge about extubation toward WC from MV:***

In our study showed that the total knowledge about extubation toward WC from MV, The results of the study showed that (58%) of the nurses had correct knowledge and (42%) had incorrect knowledge. This finding agrees with the study was conducted in Gothenburg, Sweden by ***Niraj Niranjan (2018)*** the total knowledge about extubation toward WC from MV, showed that (57.4%) of the nurses had correct knowledge and (42.6%) had incorrect knowledge.

- ***Overall knowledge toward weaning criteria from MV:***

The present study showed that the overall knowledge of ICU nurses toward WC from MV showed that (54%) of the nurses had correct knowledge toward weaning criteria from MV, whereas (46%) of them had incorrect knowledge, also our results are an disagreement with the study was conducted by ***Mamta Thapa (2013)*** in Bangalore, Indian that. The results of the study showed that the overall knowledge of ICU nurses toward WC from MV showed that (43.6%) of the nurses had correct knowledge toward weaning criteria from MV, whereas (56.4%) of them had incorrect knowledge.

- ***Level of knowledge toward weaning criteria from MV:***

In the light of the current study results. The study reveal that half of studied nurses (50%) had moderate knowledge level and (39%) had poor knowledge level of total score knowledge of nurses regarding weaning criteria from MV. In the same line, **Pradhan and Shrestha, (2017)** who study nurses' knowledge regarding weaning criteria of mechanical ventilation in a teaching hospital, Chitwan, found that 54.4% of nurses had inadequate knowledge regarding weaning criteria. This finding is relative agrees with the study was conducted in Uttar Pradesh, India by ***Talwar (2016)***. Weaning from MV in chronic obstructive pulmonary disease care nursing regarding evidence-based guidelines for weaning criteria from MV, who found there was (48.8%) of ICU nurses had a satisfactory knowledge regarding guidelines for weaning criteria from MV.

- ***Overall knowledge toward weaning criteria from MV:***

The current study has found that there was no significant differences in the overall knowledge scores toward weaning criteria from MV according to demographic characteristics (P-value>0.05). This is similar to the results of the study was conducted on knowledge and practice of intensive care nurses on weaning criteria from MV by ***Carter*** **(2012)** in Muncie, Indiana, this has indicated that there is no differences according demographic characteristics. Furthermore, this is similar to the findings by ***Bal, Kumari*** **(2017)** in Toronto, Canada study worked, this indicated there is no statistically significant differences in the overall knowledge toward criteria weaning from MV by demographic characteristics of ICU nurses.

Pradhan and Shrestha, **(2017)** who study nurses' knowledge regarding weaning criteria of the patients with mechanical ventilation in a teaching hospital, Chitwan, found association between level of knowledge regarding weaning criteria with age ($p\leq 0.006$), professional experience ($p \leq 0.001$), clinical areas ($p=0.002$) and professional experience in critical area ($p \leq 0.001$). Those explanation and findings are in the opposite side with current study. ***Darshan K, et al., (2009)*** who assessed the knowledge of staff nurses on mechanical ventilation and found that there is no significant association between knowledge scores of staff nurses in relation to their demographic data. This was a good supportive to the finding of the present study that revealed association between overall knowledge with education level, and documentation with age.

Another study conducted in Egypt Medical Nursing, Port Said University, Deralakatte , Mangalore by ***Shehab, M, et al*** **(2018),** reported that critical area is not significant of level of knowledge on weaning criteria. As well as present study findings were agree with ***Fathimath et al.,*** **(2013)** who found that there is no association between knowledge score and demographic variables such as years of experience (p-value>0.05), ICU training (0.64), and level of education(p-value >0.5).

As regards to the training of nurses, the current study has found that a there was no significant differences in the overall knowledge toward criteria weaning from MV according to training courses and diploma (P-value>0.05) but there was significant differences in regards dot diploma degree in respiratory (P-value<0.05). This is similar to the results of the study was conducted to assess knowledge and practice of intensive care nurses on weaning criteria from MV by ***Carter (2012*****)** in Muncie, Indiana, this has indicated that there was no differences according to training courses.

On other hand, this was similar to the study was done by ***Bal Kumari (2017)*** in Toronto, Canada study worked, this indicated that there was no differences in the overall knowledge toward criteria weaning from MV by courses training of ICU nurses.

6.4 Nurses practice toward weaning criteria from MV

- ***Practice of nurses about readiness weaning toward weaning criteria from MV:***

The results of the present study showed that, most of the nurses (83.9%) were applied decrease FIO_2 40% or less, PEEP 5 cm H_2O or less. About (9.7%) of the nurses were applied assessment spontaneously breathing trial according criteria, (22.6%) were assess hemodynamic stability, or with low dose vasoactive support.

This findings were agreed with the study conducted by ***Blackwood and Wilson-barnett (2007*****)** in England to observation practice of intensive care nurses toward readiness weaning from MV, while majority of the nurses (80.3%) were applied decrease FIO_2 40% or less, PEEP 5 cm H_2O or less, while disagreed with regards to applied assessment spontaneously breathing trial according criteria (30%) and assess hemodynamic stability, or with low dose vasoactive support (35.2%).

The present study showed that (9.7%) of the nurse were assess the adequate management of pain/anxiety/agitation, (79.6%) were stop sedation and muscle relaxants drug, (61.3%) were applied mouth care and oral suctioning prior to starting, (35.5%) applied hands washing before and after oral care, tracheal suction, touch patient or equipment.

The findings of the present study approximately in line with the study conducted by ***Marybeth et al., (2017)*** in United States of America toward readiness weaning from MV, about (12%) of nurses were assess the adequate management of pain/anxiety/agitation, while the more of the nurses (70.5%) stop sedation and muscle relaxants drug, whereas of the nurses (53.7%) were applied mouth care and oral suctioning prior to starting weaning trial, and (35.4%) of them applied hands washing before and after oral care, tracheal suction, touch patient or equipment.

The present study showed that, the majority of the nurses (93.5%) were putting the patient in semi-sitting position at (30˚ to 45˚), and (35.5%) of the nurses were apply chest physiotherapy. This findings were approximately agreed with the study conducted by ***Schönhofer (2015)*** in Germany who was found the majority of the nurses (95%) were putting the patient in semi-sitting position at (30˚ to 45˚) and (40%) of the nurses apply chest physiotherapy.

- ***Practice of nurses toward weaning intervention from MV:***

The result of the present study showed that the practice of ICU nurses about weaning intervention from MV. The majority of the nurses (87.1%) discontinued MV and connect patient to T-pace tube, while the most of the nurses (78.5%) decreased FiO2, whereas more than half of the nurses (58.1%) Gradually decreased mandatory breathing, This findings were approximately disagreed with the study conducted by ***Schönhofer (2015)*** in Germany who was found the majority of the nurses (90.2%) discontinued MV and connect patient to T-pace tube, while the most of the nurses (81.1%) decreased FiO2, whereas more than half of the nurses (76.1%) Gradually decreased mandatory breathing.

the present study showed that about one third of the nurses (35.5%) convert to pressure-support ventilation (PSV), about one quarter of the nurses (24.7%) decreased the PSV as tolerated to 10 cm H2O or less, the fifth (20.4%) of them checked the ABGs and adjust MV according to results, and (14.0%) of the nurses assessed the patient for extubation criteria, moreover of the nurses (9.7%) who assessed the patient for tolerance criteria for at least 2 hours.

This finding disagreed with a study conducted by ***Breul (2013)*** in Chicago, United States of America showed that more than of the nurses (51.3%) convert to pressure support ventilation (PSV), while one third of the nurses (34.9%) decreased the PSV as tolerated to 10 cm H2O or less, and (40%) of them checked the ABGs and adjust MV according to results, On the other study disagreement conducted by **Blackwood and** ***Wilsonbarnett (2007)*** in England to observation practice of intensive are nurses toward redness weaning from MV, and (35.0%) of the nurses assessed the patient for extubation criteria, moreover of the nurses (25.3%) who assessed the patient for tolerance criteria for at least 2 hours.

- ***Total practice of ICU nurses toward weaning intervention from MV:***

This our study showed that the total practice toward weaning intervention from MV showed that (41%) of the nurses were done practice correctly and (11%) of them need correct practice and (48%) not done practices toward weaning intervention from MV. This findings approximately in line with the study conducted by ***Bal Kumari (2017)*** in Chitwan toward nurses' knowledge and practice regarding weaning criteria of the patients from MV. He found that (45.6%) of the nurses were adequate practice and (15%) of ICU nurses were need correct practice and (39.4%) of them not done practices according weaning criteria from MV.

- ***Practice of ICU nurses about extubation toward WC from MV:***

The results of the study showed little nurses (7.5%) prepare all necessary equipment for extubation and re-intubation. Most nurses (93.5%) putting patient in upright sitting position and (90.3%) oral and ETT suction, (54.8%) deflate ETT cuff. and (19.4%) of the nurses were encourage patient to take deep breathing. Whereas (36.6%) smoothly take out ETT (23.7%) apply suction of oral cavity and ask patient to cough. Majority of the nurses (93.5%) placed patient on supplemental oxygen afterward. Whereas (20.4%) documentation before, during, after weaning process.

This finding is disagreed with a study conducted by ***Mamta Thapa (2013*****)** in Bangalore, Indian that. The results of the study showed little nurses (17.1%) prepare all necessary equipment for extubation and re-intubation. Most nurses (84.5%) putting patient in upright sitting position during weaning from MV and (88.6%) oral and ETT suction.

This finding is agreed with a study conducted by ***Nathan Woody (2013)*** Johannesburg in South Africa, while the most of nurses (70.1%) were deflate ETT cuff. and one quarter of the nurses (25.2%) encourage patient to take deep breathing.

This finding disagreed with a study conducted by ***Breul (2013)*** in Chicago, United States of America showed regarding to smoothly take out ETT(41.3%) of the nurses, apply suction the oral cavity and ask patient to cough (50.5%) of ICU nurses but is agreed in regards to placed patients on supplemental oxygen afterward (95%) and documentation before, during, after weaning process (21.6%).

- ***Level of practice among ICU nurses toward WC from MV***

On respect of, total score of nurses' level of practice regarding weaning from mechanical ventilation in the current study. The results shows that approximately half of studied nurses had poor level of practice and (15%) of them good level practice and (36%) 0f the nurses had moderate satisfactory practice level, In the same line with ***Mariam et al., (2018)*** they done a study on nurses' performance regarding weaning of patient's from mechanical ventilation, mentioned that more than half of the studied nurses had un satisfactory practices level regarding weaning of patient from MV and (34%) of them had satisfactory practice level regarding WC from MV. This results disagree with ***Osman (2017)*** who done a study on nurses' performance regarding weaning of patient's from mechanical ventilation, mentioned that (73.3%) of the studied nurses had satisfactory practice level regarding weaning of patient from mechanical ventilation.

- ***Overall practice toward weaning criteria from MV by demographic characteristics:***

The current study has found that a significant differences in the overall practice toward criteria weaning from MV and age, level of education and experiences of nurses (P-value<0.05), this is similar to the results of the study was conducted by ***Garriga and Rodríguez (2016)*** in Catalunya toward the overall practice toward criteria weaning from MV and age, level of education and experiences of nurses (P-value<0.05).

6.4 Limitations of the study

The current study was conducted in ICUs of 4 public hospitals in Sana, a city, had few numbers of participants, therefore findings may not be representative of the general population of ICU nurses in Yemen. This may threaten the external validity of the findings hence another research on this area with a large sample size is required.

Observation, like other methods, has its own limitations and ethical implications. One of the main problems is the effect of the 'observer' on the 'observed'. This is referred to as the Hawthorne effect and is an important threat to the validity of observational research, whereby participants' awareness of being in a study may cause them to change their practice ***(Pradhan and Shrestha, 2017: Wang, et al,, 2015; Ouellette, et al ,2017).*** However the literature suggests that the change of behavior is usually temporary, where there is a tendency for the observed to become used to the presence of the observer and continue to perform their activities according to their normal day-to-day practice ***(J.M. Cairo, 2016).*** Therefore, the Hawthorne effect may not have affected the study findings.

Chapter Seven: Conclusion and Recommendations

7.1 Conclusion

From the results of this study, we conclude that:

- ***Knowledge outcomes:***
    - The total correct knowledge about readiness respiratory and hemodynamic to weaning from MV among nurses was (51%).
    - The total correct knowledge about other screening readiness to weaning from MV among nurses was (53%).
    - The total correct knowledge about modes weaning intervention from MV. was (51%)
    - The total correct knowledge about recommendation parameters of weaning intervention from MV was (52%).
    - More than half (59%) of the nurses had total correct knowledge about tolerance criteria for weaning from MV.
    - More than half (58%) of the nurses had total correct knowledge about extubation toward weaning criteria from MV.
    - The overall knowledge for all items of weaning criteria from MV showed that (54%) of the nurses had correct knowledge toward weaning criteria from MV whereas (46%) had incorrect knowledge.
    - The level of knowledge for all items of weaning criteria from MV showed that (50%) of the nurses had moderate level of knowledge and (39%) of the nurses had poor level of knowledge, whereas (11%) of the nurses had good level of knowledge.

- There was no statistically significant differences in the mean knowledge scores toward weaning criteria from MV according to demographic characteristics of ICU nurses (P-value>0.05).
- A significant differences in the mean knowledge scores toward weaning criteria from MV by diploma degree in respiratory therapy (P-value< 0.05) while there was no statistically significant differences in related to courses training in ICU and course training in weaning criteria (P-value>0.05). .
- There was no significant association between level of knowledge toward criteria weaning from MV and workplace (P-value > 0.05).

- ***Practices outcomes:***
  - The total correct practices about readiness for weaning from MV among nurses was (42%).
  - The total correct practices about weaning intervention from MV was (41%) .
  - The total correct practices about extubation toward weaning criteria from MV was (49%)
  - The overall practices for all items of weaning criteria from MV showed that (44%) of the nurses were correctly practiced all procedures toward weaning criteria from MV.
  - The level of practices for all items of weaning criteria from MV showed that 49% of nurses had a poor level of practice, (36%) had moderate level of practices and (15%) had a good level of practices.
  - A statistically significant difference was found in the mean practice scores by demographic characteristics (P-value<0.05) except for sex (P-value>0.05).

- There was statistically significant differences in the overall practices toward criteria weaning from MV by training (P-value<0.05).
- There was a significant association between the level of practices toward criteria weaning from MV and workplace (P-value < 0.05).

7.2 Recommendations

With increasing advances in the health sciences, including nursing science and there is a rising need for constant updating of new information to develop new skills and mode in order to provide the best care to patients. To fulfill this need ICU nurses need ongoing development in their careers in order to remain updated with current knowledge and skills. ***We recommended that:***

- ***Recommendations for Nursing Education***

The following recommendations made for nursing education:

1. Resources such as articles journals and electronic resources such as computers and the internet should be made accessible in the units for staff members. Articles on criteria weaning from MV should be discussed in unit meetings as part of staff education.
2. The ICU training program should include evidence-based guidelines for the criteria weaning from mechanical ventilation.
3. Nursing lecturers and clinical facilitators should incorporate evidence-based how is assessed patient on ventilator according weaning criteria daily in ICU's and use learning opportunities in the units to raise the topic
4. The continuing professional development program should be made compulsory for nurses to motivate nurses to participate in lectures, and another program in order to increase their knowledge and practice levels.

- ***Recommendations for Clinical Practices***

    1. The usage of the weaning protocol should be encourage.
    2. Daily /on even shift comprehensive assessment on patients should be done
    3. Training on identification of weaning failure.
    4. Continuous assessment of the patients who is being weaned to detect early signs of failure.

- ***Recommendations for Nursing Research***

    Recommendations for further research based on the limitations of this study. The recommendations include the following:

    1. A similar study is recommended to include a large sample size in other hospitals and possibly other provinces with a larger population and sample. which provide care for critically ill patients in Yemen.
    2. Further research on factors affecting implementation of weaning strategies is recommended
    3. Further research should be conducted to test knowledge and practice levels of nurses prior to and after the educational program on evidence-based guidelines for weaning criteria and long-term for Patients Requiring Prolonged Ventilation.

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Appendix A : Questionnaire and Inform consent
Arabic Version

استبيان رقم (١)

النسخه بالغة العربية

اداة رقم واحد
تقييم معارف وممارسات ممرضي العناية المركزة حول معايير فطام المريض من جهاز التنفس الاصطناعي في المستشفيات العامة مدينة صنعاء – اليمن.
الجزء الاول : الموافقة الرسمية

- **عزيزي/عزيزتي زملاء المهنة: انا الباحث عبد اللطيف احمد محمد فارع الجنيد من كلية العلوم الطبية ـجامعة الرازي اقوم بأجراء رسالة الماجستير في مجال تمريض الحالات الحرجة، واجري هذه الرسالة بموافقة جامعة الرازي والهدف منها هو تقييم معارف وممارسات ممرضي العناية المركزة حول معايير فطام المريض من جهاز التنفس الاصطناعي في المستشفيات العامة مدينة صنعاء-اليمن.**
- **المشاركة في هذه الدراسة هي تطوعية والمعلومات التي سنأخذها منك ستحاط بالسرية التامة وفقا لأخلاقيات البحث العلمي . نرجو اعطانا الاجابات التي تعبر عن معرفتك انت فقط. وبإمكانكم الاستفسار عن أي شيء في الرسالة من خلال التواصل بنا على التلفون (770606094) او على الإيميل (algonad55@hotmail.com).**

الجزء الاول : البيانات الديموغرافية

من فضلك ضع دائرة حول الإجابة الصحيحة:

م	السؤال	الاجابة المتوقعة الصحيحة	الرمز
.١	**اسم المستشفى**	• مستشفى الثورة	١
		• مستشفى الجمهوري	٢
		• مستشفى الكويت	٣
		• مستشفى السبعين	٤
.٢	**اسم وحدة العناية المركزة**	• وحدة العناية المركزة العامة	١
		• وحدة العناية المركزة الأطفال	٢
		• وحدة العناية المركزة الطوارئ	٣
		• وحدة العناية المركزة الجراحة	٤
		• وحدة العناية المركزة الباطنة	٥
		• اخرى	٦
.٣	**الجنس**	• ذكر	١
		• انثى	٢
.٤	**الحالة الاجتماعية**	• غير متزوج	١
		• متزوج	٢
.٥	**العمر بالسنة**	•	
.٦	**المستوى التعليمي**	• درجة الدبلوم	١
		• درجة البكالوريوس	٢
		• درجة الماجستير	٣
		• درجة اخرى	٤
.٧	**سنوات الخبرة في العناية المركزة بالسنة**	....	

الجزء الثاني : البرنامج التدريبي

م	السؤال	الاجابة	الرمز
.٨	**هل حصلت على درجة علمية او كرس تدريبي في العناية المركزة**	• نعم	١
		• لا	٢
.٩	**هل يوجد في المستشفى سياسه او بروتوكول (protocol) مكتوبة لفطام المريض من جهاز التنفس الاصطناعي.**	• نعم	١
		• لا	٢
.١٠	**هل حصلت على كرس تدريبي حول معايير فطام المريض من جهاز التنفس الاصطناعي**	• نعم	١
		• لا	٢
.١١	**هل حصلت على دبلوم معالجة تنفسية بعد شهادة التمريض.**	• نعم	١
		• لا	٢

الجزء الثالث: معارف ممرضي العانية المركزة حول معاير فطام المريض من جهاز التنفس الاصطناعي. (من فضلك ضع دائرة حول الإجابة الصحيحة)		
المقطع الاول: المعارف تجاه تقيم معاير فطام المريض من جهاز التنفس الاصطناعي.	**نعم**	**لا**
١. المعايير المستخدمة لتقييم تحمل المريض للتنفس التلقائي عند محاولة الفطام ؟		
أ- تبادل غازات الدم بشكل كافي.		
ب- استقرار نمط التنفس		
ت- استقرار ديناميكية الدورة الدموية.		
ث- استقرار الحالة العقلية.		
٢. المعايير الصحيحة للأوكسجين الكافي لتحديد الفطام.		
أ- $SpaO_2 \geq 60$ mmHg with $FiO_2 < 0.4$		
ب- $SaO_2 > 90$ % at FiO_2 up to 0.4.		
ت- Ratio of $paO_2 > 150$ to 200 mmHg .		
ث- $FiO_2 \leq 0.4$ to 0.5 and $pH \geq 7.25$.		
٣. المعايير الصحيحة لتقيم استقرار الدورة الدموية لتحديد الفطام		
أ- ضغط الدم الانقباضي اكبر من ٩٠ واقل من ١٨٠(mmhg).		
ب- نسبة حجم كرويات الدم الحمراء في الدم (Hematocrit) اكثر من ٢٥%.		
ت- معدل ضربات القلب اقل من ١٤٠ نبضة لكل دقيقة.		
ث- يحتاج الى جرعة عالية من ادوية انقباض الاوعية الدموية (vasoactive drugs).		
٤. المعايير الصحيحة لتقيم التنفس لجاهزية الفطام؟		
أ- معدل التنفس اقل من ٣٥ نفس لكل دقيقة.		
ب- PEEP $\leq$ 2-7 cm H_2O, $pH \geq 7.50$, RR $\leq$ 7 bpm.		
ت- PH ≥ 7.32 - < 7.45, PEEP $\leq$ 5 cm H_2O.		
ث- درجة الحرارة اكثر من ٣٦ واقل ٣٩ درجة مئوية.		
المقطع الثاني: المعارف الاخرى تجاه تقيم معاير فطام المريض من جهاز التنفس الاصطناعي.		
٥. المشكلة التي تسببت في دخول المريض على جهاز التنفس الاصطناعي يجب ان تكون؟		
أ- حلت المشكلة		
ب- قلة حدة المشكلة		
ت- بقاء المشكلة		
ث- تحسن المريض.		
٦. المعايير الصحيحة عند التنفس التلقائي لجاهزية الفطام؟		
أ- حالة المريض مستقرة.		
ب- المريض غير مجهده		
ت- المريض يشعر بالراحة افضل من بقائه على جهاز التنفس الاصطناعي		
ث- المريض يسعل بشكل كافي وقلة الإفرازات المفرطة.		
٧. الفطام من التنفس الاصطناعي لفترة طويلة تعني؟		
أ- المريض على جهاز التنفس الاصطناعي اكثر من ٧٢ ساعة.		
ب- فشل المريض لمحاولة الفطام لفترة قصيرة		
ت- المريض يحتاج الى فترة زمنية لاستعادة قوة عضلات التنفس		
ث- المريض قادرا على تحمل الفطام من يومين الى ثلاثة ايام.		

المقطع الثالث: المعارف تجاه التدخلات التمريضية في مودات الفطام المريض من جهاز التنفس الاصطناعي.		
٨. اي من مودات جهاز التنفس الاصطناعي تستخدم لفطام المريض؟		
أ- مود جهاز التنفس الاصطناعي المتناغم المتقطع الإلزامي (SIMV).		
ب- مود جهاز التنفس الاصطناعي الداعم بالضغط (PSV).		
ت- محاولة التنفس التلقائي.		
ث- مود جهار التنفس الاصطناعي ذات التحكم الكامل بالضغط (PCV).		
٩. تكرار محاولة الفطام من مود جهاز التنفس الاصطناعي الداعم بالضغط بعد فترة الراحة يجب ان يكون؟.		
أ- بعد ٢٤ ساعة عند الفطام على المدى الطويل.		
ب- الحد الأدنى بعد ساعتين.		
ت- بعد فشل تجربة الفطام للمرة الثانية يعاد الى وضع الراحة.		
ث- بعد ٢٤ ساعة لكل المرضى.		
١٠. القيم الصحيحة لجاهزية الفطام من جهاز التنفس الاصطناعي؟.		
أ- أقصى ضغط الشهيق اكبر من - ٣٠ سم H_2O في ٢٠ ثانية.		
ب- كمية التهوية لكل دقيقة اقل من١٠ لتر في الدقيقة (Minute ventilation < 10 L/min)		
ت- كمية الهواء التلقائي لكل نفس اكبر من ٥ مل/ كجم (Tidal volume > 5ml/kg)		
ث- السعة الحيوية للرئه اكبر من ٢٠ مل / كجم (Vital capacity > 20 mL/kg)		
المقطع الرابع: المعارف الموصي بها تجاه التدخلات التمريضية في مودات الفطام المريض من جهاز التنفس الاصطناعي.		
١١. الوقت الموصي به لعمل تقيم للمريض أثناء الفطام يجب ان يكون؟		
أ- تقيم غازات الدم الشرياني(ABG) بعد ٣٠ دقيقة من التنفس التلقائي		
ب-تقيم العلامات الحيوية كل ١٥ دقيقة خلال الساعة الاول من الفطام ومن ثم حسب روتين الوحدة.		
ت-تجربة التنفس التلقائي من ٣٠ – ١٢٠ دقيقة.		
ث-المراقبة المستمرة لتشبع الدم بالاكسجين (SPO2).		
١٢. التوصيات الصحيحة في العناية التمريضية خلال عملية الفطام؟.		
أ- الشفط المعقم بأنتظام		
ب- المحافظة على المريض في وضعية شبة جالس بزاوية ٣٠ – ٤٥ درجة		
ت- التوثيق لإجراءات الفطام		
ث- استخدام خطة لتنظيم الفطام		
١٣. استخدام مودات الفطام من جهاز التنفس الاصطناعي يجب ان؟		
أ- يحول من مود CMV الى مود SIMV		
ب- يحول من مود SIMV الى مود PS		
ت- يحول من مود CMV الى مود CPAP		
ث- يحول من مود PS الى مود CPAP		
المقطع الخامس: المعارف تجاه معاير تحمل الفطام من جهاز التنفس الاصطناعي.		
١٤. مؤشرات فشل تحمل المريض للفطام		
أ- كمية الهواء التلقائي لكل نفس اقل من ٥ مل/ كجم(.Tidal volume < 5ml/kg)		
ب- ضغط ثاني اكسيد الكربون اكبر من ٥٠ مم زئبق ($PaCO_2$ > 50 mmHg)		
ت- نسبة تشبع الدم بالأكسجين اقل من ٩٠% (SaO_2< 90%).		
ث- معدل التنفس اكثر من ٣٥ نفس بدقيقة		
١٥. علامات فشل تحمل المريض للتنفس التلقائي ؟		
أ- استخدام عضلات التنفس المساعدة		
ب- صعوبة في التنفس		
ت- نقص تشبع الاكسجين في الدم		
ث- تعرق غزير (Diaphoresis)		

	نعم	لا
١٦. علامات فشل استقرار الدورة الدموية لتحمل الفطام من جهاز التنفس الاصطناعي؟	نعم	لا
أ- الضغط الانقباضي اقل من ٩٠ واكبر من ١٨٠ مم زئبق		
ب- درجة الحرارة اكثر من ٣٩ درجة مئوية وأقل من ٣٦ درجة مئوية		
ت- معدل ضربات القلب اكثر من ١٤٠ دقه بدقيقة		
ث- معدل التنفس اقل من ٤٥ نفس بدقيقة		
١٧. ما هو أفضل مود غير مجهد ومريح للمريض بعد فشل الفطام من جهاز التنفس الاصطناعي؟		
أ- CPAP		
ب- SIMV		
ت- PSV		
ث- T.peice		
المقطع السادس: المعارف تجاه نزع الأنبوب الرغامي (Extubation).		
١٨. معايير نزع الأنبوب الرغامي (Extubation)؟		
ج- قلة الافرازات عند المريض		
ح- انفتاح المجاري التنفسية بشكل مثالي.		
خ- المريض قادر على حماية مجاري التنفس.		
د- مستوى الوعي اكبر من ٨ (GCS > 8)		
١٩. القيم الصحيحة تجاه معاير نزع الانبوب الرغامي هي؟		
أ- معدل التنفس من ١٣ الى اقل من ٣٠ نفس بدقيقة.		
ب- كمية الهواء التلقائي لكل نفس اكبر من ٥ مل/ كجم (Tidal volume > 5ml/kg)		
ت- نسبة تشبع الدم بالأكسجين اكبر من ٩٠% (SaO_2> 90%) .		
ث- السعة الحيوية للرئه اكبر من ١٥ مل / كجم (Vital capacity > 15 mL/kg)		
٢٠. استراتيجيات التخدير والمعالجة التنفسية التي تهدف الى نزع الأنبوب الرغامي في وقت مبكر ينبغي أن تتطبق؟		
أ- للمريض بعد العملية الجراحية مباشرتا		
ب- للمريض أثناء الاقامة في وحدة العناية المركزة		
ت- بعد اسبوع من الاقامة في وحدة العناية المركزة		
ث- المريض الذي يعاني من مرض لا رجعة فيه مثل إصابة الحبل الشوكي.		

شكرا لمشاركتك،،،

Appendix A : Questionnaire and Inform consent
English Version

Questionnaire No. (   )

Research Title
Knowledge and practice of intensive care nurses' towards weaning criteria from mechanical ventilation at public hospitals in Sana'a City-Yemen.
Informed consent
• Dear colleague: I am a researcher (**Abdullateef Ahmed Mohammed Al-Gunaid**) from college of Medical Sciences - Al-Razi University. I undertake a master's thesis in the field of the critical care nursing that aims to assessment of knowledge and practice of the ICU nurses' towards weaning criteria from ventilator at public hospitals in Sana'a City-Yemen. • Participation in this study is voluntary and the information that we will take from you was subject to strict confidentiality in accordance with the ethics of scientific research, and will not be affected in your profession or work by the information you give, and the identity of the participant will not know. • Please give us the answers that reflect your knowledge only. • Thank you for giving us part of your time to read this information. You can inquire about anything in the message by contacting us at (770606094) or on the Email (**algonaid55@hotmail.com**).

Part II : Demographic characteristics of Nurses			
Please Circle on the correct answer			
QN	**Statement**	**Expected answer**	**Code**
1.	**Hospital Name**	• Al-Thowrah hospital	**1**
		• Al-Jomhury hospital	**2**
		• Al-Kuwait hospital	**3**
		• Al-Sabeen hospital	**4**
2.	**Type of ICU**	• General ICU	**1**
		• Pediatric ICU	**2**
		• Emergency ICU	**3**
		• Surgical ICU	**4**
		• Medical ICU	**5**
		• Other specify.........................	**6**
3.	**Sex**	• Male	**1**
		• Female	**2**
4.	**Marital status**	• Single	**1**
		• Married	**2**
5.	**Age in (Years)**	• ………………………………	
6.	**Level Education**	• Diploma degree	**1**
		• Bachelor degree	**2**
		• Master degree	**3**
		• Other specify …………….	**4**
7.	**Years of ICU Experience**	• ……………..........................	

Part II: Courses Training.			
QN	**Statement**	**Expected answer**	**Code**
1.	**Do you have a degree or courses training in ICU?**	• Yes	**1**
		• No	**2**
2.	**There are writing weaning protocol in your hospital.**	• Yes	**1**
		• No	**2**
3.	**Do you have courses training about weaning criteria from mechanical ventilation?**	• Yes	**1**
		• No.	**2**
4.	**Do you have diploma in respiratory therapy?**	• Yes	**1**
		• No.	**2**

Part III- ICU nurses knowledge about weaning criteria from mechanical ventilation (Please choose the correct answer)		
Section I: Knowledge of nurses about screening respiratory and hemodynamic toward weaning criteria from MV.	**Yes**	**No**
1. A criteria used to assess patient tolerance of spontaneously breathing is?		
A. Adequate gases exchange.		
B. Respiratory pattern.		
C. Hemodynamic stability.		
D. Mental status within normal.		
2. Adequate oxygenation for weaning means؟		
A. $SpaO_2 \geq 60$ mmHg with $FiO_2 < 0.4$.		
B. Ratio of $SpaO_2 > 150$ to 200 mmHg.		
C. $FiO_2 \leq 0.4$ to 0.5 and pH≥ 7.25.		
D. $SaO_2 > 90$ % at FiO2 up to 0.4**.**		
3. The hemodynamic stability for weaning criteria?		
A. Systolic blood pressure > 80 - < 160 mmHg.		
B. Hematocrit more than 25%.		
C. Heart rate < 140 beat/minute.		
D. High dose vasoactive support**.**		
4. The respiratory screening to wean from MV is?		
A. PH ≥ 7.32 - < 7.45, PEEP ≤ 5 cm H_2O.		
B. PEEP $\leq$ 2-7 cm H_2O, pH≥ 7.50, RR ≤ 7 bpm.		
C. Respiratory rate < 35 breath/min.		
D. Temperature more than 36 C° - less than < 39 C°.		
Section II: Other screening readiness toward weaning criteria from MV.		
5. The problem that causes the patient requires MV must be?		
A. Resolved problem		
B. Reduced the severity problem.		
C. Still the problem.		
D. Improve patient.		
6. Patient on spontaneously breathing should?		
A. Stable condition.		
B. None fatiguing.		
C. Confortable from mechanical support.		
D. Adequate cough and absence excessive secretion.		

7. A weaning from long-term ventilation means.		
A. Patient in the mechanical ventilation > 72 hours.		
B. Patient failed short-term weaning.		
C. Patient require a period of regain strength of respiratory muscle.		
D. Patient has tolerance tow to three daily weaning.		
Section III: knowledge about modes weaning intervention from mechanical ventilation.		
8. Which the mode ventilator support patient need weaning?		
A. Synchronized intermittent mandatory ventilation (SIMV)		
B. Pressure support ventilation (PSV)		
C. Spontaneous breathing trial		
D. Pressure control mode.		
9. Repeat wean attempt on pressure support ventilation mode after rest period?		
E. After 24 hours when long-term ventilation weaning.		
F. A minimum after 2 hour.		
G. Patient fails second weaning trial return to rest setting.		
H. After 24 hours for all patient.		
10. The correct recommendation parameter for weaning criteria?		
A. Maximum inspiratory pressure > - 30 cm H_2O in 20 second.		
B. The Minute ventilation < 10 L/minute.		
C. Tidal volume spontaneously breathing > 5ml/kg.		
D. Vital capacity > 20 mL/kg.		
Section IV: knowledge about recommendation parameters weaning intervention from MV.		
11. A recommended time for assess the patient during weaning?		
E. ABG after 30 minutes of spontaneous breathing.		
F. vital signs every 15 minutes through one hour then routine for unit.		
G. Spontaneously breathing trial 30 – 120 minute.		
H. Continuous monitoring SPO_2.		
12. A recommendation nursing care during weaning is?		
A. Regular sterile suctioning.		
B. Keeps the patient in semi sitting position 30- 45 degree.		
C. Documentation weaning process.		
D. Use a plan to regulate weaning.		
13. During weaning the patient from mechanical ventilation you should?		
A. Converted from mode CMV to SIMV.		
B. Converted from mode SIMV to PS.		
C. Converted from mode CMV to CPAP.		
D. Converted from mode SP to CPAP.		
Section V: Tolerance criteria for weaning from MV.		
14. An indicator for weaning failure?		
A. Tidal volume 5m/kg or less.		
B. $PaCO_2$ > 50 mmHg.		
C. SaO_2 less than 90%.		
D. Increased RR > 35 breath/minute.		

15. Failure of spontaneously breathing trial?		
A. Use of accessory muscles.		
B. Dyspnea.		
C. Hypoxemia.		
D. Diaphoresis.		
16. Failure hemodynamic stability for tolerance weaning failure is?		
A. Systolic blood pressure <90 - > 180 mmHg.		
B. Temperature < 36 - > 39 C◦.		
C. Heart rate > 140 beat/minute.		
D. Respiratory rate < 45 breath/min.		
17. Which is the best mode not fatiguing and comfortable patient after fail weaning?		
A. CPAP.		
B. SIMV.		
C. PSV.		
D. T.peice.		
VI. Knowledge toward extubation.		
18. Extubation criteria is?		
A. The patient less secretion.		
B. airway patency.		
C. Patient able to protection airway.		
D. GCS > 8.		
19. Parameter for extubation criteria?		
A. RR > 13 - < 30 breath/minute.		
B. VT > 5 mL/kg.		
C. SaO2 > 94% on FIO_2 .40%.		
D. Vital capacity > 15 mL/kg.		
20. Anesthesia/sedation strategies & ventilator management that aimed to early extubation should be used at?		
A. Post-surgical patient.		
B. During stay in ICU.		
C. After weak for patient stay in ICU.		
D. for the patient irreversible disease.		

Thank you for your participation!!!

Tool two - Observational check list on ICU nurses practice toward weaning criteria from mechanical ventilation			
Weaning Criteria Practice	**Done**	**Need correct**	**Not done**
Part I: Readiness for weaning from MV.			
1. Decrease FIO_2 40% or less, PEEP 5 cm H_2O or less.			
2. Assessment spontaneously breathing trial according criteria.			
3. Assess hemodynamic stability, or with low dose vasoactive support			
4. Assess the adequate management of pain/anxiety/agitation.			
5. Stop sedation and muscle relaxants drug.			
6. Mouth care and oral suctioning prior to starting weaning trial.			
7. Apply hands washing before and after oral care, tracheal suction, touch patient or equipment.			
8. Putting the patient in semi-sitting position at (30˚ to 45˚).			
9. Apply chest physiotherapy.			
Part II: Weaning intervention.			
10. Gradually decreasing mandatory breathing.			
11. Gradually decrease Fio2.			
12. Convert to pressure-support ventilation (PSV).			
13. Decrease the PSV as tolerated to 10 cm H_2O or less.			
14. Assess the patient for tolerance criteria for at least 2 hours.			
15. Check the ABGs and adjust MV according to results.			
16. Discontinued MV and connect patient to T-pace.			
17. Assess the patient for extubation criteria			
Part III: Extubation.			
18. Prepare all necessary equipment for extubation and re-intubation.			
19. Putting patient in upright sitting position.			
20. Oral and ETT suction.			
21. Deflate ETT cuff.			
22. Encourage patient to take deep breathing.			
23. Smoothly take out ETT.			
24. Suction the oral cavity and ask patient to cough.			
25. Placed patient on supplemental oxygen afterward.			
26. Documentation before, during, after weaning process.			

Appendix-B
Litters to principles of hospitals

Republic of Yemen
Ministry of Higher Education and Scientific Research
Al-Razi University

الجمهورية اليمنية
وزارة التعليم العالي والبحث العلمي
جامعة الرازي

الأخ/ مدير عام هيئة مستشفى الجمهوري التعليمي المحترم

تحية طيبة وبعد ،،،

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"Knowledge and Practice of ICU nurses toward criteria of weaning from mechanical ventilation at public hospitals in Sana'a City Yemen"

وعليه:

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وتقبلوا خالص الشكر والتقدير،،،

نائب رئيس الجامعة للدراسات العليا

أ.د/نبيل الربيعي

12.1.2020

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