"ULTRASONOGRAPHY OF THE DIAPHRAGM TO PREDICT SUCCESSFUL EXTUBATION"

By

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DISSERTATION SUBMITTED TO SRI DEVARAJ URS ACADEMY OF HIGHER EDUCATION AND RESEARCH CENTER, KOLAR, KARNATAKA

In partial fulfillment of the requirements for the degree of

DOCTOR OF MEDICINE

IN

ANAESTHESIOLOGY

Under the Guidance of

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ABBREVATIONS

ICU	Intensive Care Unit
USG	Ultrasound
GCS	Glasgow Coma Scale
PaO2	Partial Pressure of Oxygen
PaCO2	Partial Pressure of Carbon
FiO2	Fraction of inspired oxygen
PEEP	Positive end expiratory pressure
mm	Millimeter
Kg	Kilogram
cm H2O	Centimeters of water Column
PaCO2	Partial Pressure of carbon dioxide
HR	Heart Rate
bpm	Beats per minute
cpm	Cycles per minute
dTF	Diaphragmatic Thickening Fraction
DE	Diaphragmatic Excursion
SBT	Spontaneous Breathing Trial
cm	Centimeter
BP	Blood Pressure
L1	Lumbar vertebrae 1
L2	Lumbar vertebrae 2
T8	Thoracic vertebrae 8
T10	Thoracic vertebrae 10
T12	Thoracic vertebrae 12
IVC	Inferior Vena Cava
C3	Cervical Vertebrae 3
C5	Cervical vertebrae 5
Hz	Hertz
eg	Example
f	Frequency/Breaths

Mhz	Megahertz
FAST	Focussed Assessment with Sonography in Trauma
B-Mode	Brightness Mode
M-Mode	Motion Mode
2D	Two Dimensional
CVS	Cardiovascular System
RS	Respiratory System
mmHg	Millimeter of Mercury
TV	Tidal Volume
L	Litre
ml	Millilitre
ml/Kg	Millilitre per Kilogram
BMI	Body Mass Index
kg/m2	Kilogram per meter square
MV	Minute Ventilation
RSBI	Rapid Shallow Breathing Index
ABG	Arterial Blood Gas
SpO2	Peripheral capillary oxygen saturation
PS	Pressure Support
CPAP	Continuous Positive Airway Pressure
SBP	Systolic Blood Pressure
DBP	Diastolic Blood Pressure
SCA	Subcoastal Area
ZOA	Zone Of Approximation

Tinsp	Thickness in inspiration
Texp	Thickness in expiration
LUS	Lung Ultrasound
SD	Standard Deviation
RR	Respiratory rate
MAP	Mean Arterial Pressure
Sl.No	Serial Number
No	Number of

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ABSTRACT

ULTRASONOGRAPHY OF THE DIAPHRAGM TO PREDICT SUCCESSFUL EXTUBATION

INTRODUCTION

An intensivist's job has never been easy when it comes to weaning off mechanical ventilation and extubation because both prolonged ventilation and early extubation are linked to a myriad of issues. Prolonged mechanical ventilation is associated with complications such as ventilatory associated pneumonia, barotrauma, atrophy of respiratory muscles. Premature extubation can result in hypoxia, hypercarbia and increased respiratory and cardiac distress.

For optimal functioning of the diaphragm, the primary muscle of inspiration, it is important to resume spontaneous ventilation after extubation irrespective of the cause for respiratory failure.

Currently ultrasonography measurement has been studied to predict the success of extubation along with other standard extubation protocols.

OBJECTIVES OF THE STUDY

1. To measure the diaphragmatic thickening fraction (dTF) and diaphragmatic excursion (DE) before and after spontaneous breathing trial (SBT).

2.To compare dTF and DE with standard extubation criteria in predicting extubation outcome.

MATERIALS AND METHODS:

This is a prospective, double blind observational study.

- Number of patients were 41
- Informed consent was taken from the patient's attenders

RESULT:

We observed that 68.29% of the patients with normal dTF and DE values were extubated successfully, 21.95% were still extubated successfully with slightly lower values of dTF and DE and 7.31% of patients were reintubated with normal dTF and DE values,2.43% was extubated onto NIV.

CONCLUSION:

In this study we concluded that in 68.29% of cases for dTF>35% and DE >1cm were successfully extubated along with standard parameters.

KEY WORDS: Extubation, Spontaneous breathing trial, Ultrasonography of Diaphragm.

INTRODUCTION

Mechanical ventilation is indicated for the treatment of acute respiratory failure triggered by a number of underlying medical conditions, trauma, or in the post-operative period in the ICU.The main responsibility of an anesthesiologists is to render adequate mechanical ventilation to the patient. It is also a challenge to decide when to wean off patients from ventilator.When assessing if a patient can be extubated effectively, timing is crucial.[1]

Weaning successfully off mechanical ventilation and extubation is always a challenge for an intensivist because both extended ventilation and premature extubation are linked to a variety of comorbidities, resulting in increased patient costs and duration of stay in the ICU.Prolonged ventilation are associated with complications such as ventilator associated pneumonia, barotrauma, atrophy of respiratory muscles.Premature extubation can result in hypoxia, hypercarbia and increased respiratory and cardiac distress.[2]

Hence, weaning should be considered once the patient is able to sustain spontaneous breathing. This decision is made based on correction of the underlying pathology, improvement in patient's GCS, airway protective mechanism, ability to cough, haemodynamic stability and no other acute problems. [3]

Routinely a checklist is followed for candidates fit for a trial of spontaneous breathing.These are as follows:[4]

1)<u>Respiratory Criteria:</u>

- PaO_2/FiO_2 > 150-200 mm Hg with FiO_2 equal to or less than to 50% and PEEP less than or equal to 8cm H_2O
- $PaCO_2$ normal or at baseline level
- Patient is able to initiate an inspiratory effort.

2) <u>Cardiovascular Criteria:</u>

- No evidence of myocardial ischemia
- Heart Rate less than or equal to 70-90 beats per minute.
- Blood pressure adequate with minimal or no vasopressors.

<u>3) Appropriate Mental Status:</u>

- Patient is arousable, or Glasgow Coma Scale more than or equal to 13.

<u>4) Absence of Correctible Comorbid Conditions</u>

- No Fever
- No Significant Electrolyte Abnormalities [5,6]

There were many protocols developed for identification of the appropriate time for extubation, but none of the protocols could accurately time the extubation. More recently, lung ultrasound and diaphragm methods have been introduced, assessing pulmonary airway patterns and diaphragmatic functions.

Optimal functions of the diaphragm, which is the primary muscle of inspiration, is important to resume spontaneous ventilation after extubation irrespective of the cause for respiratory failure.

Currently the measurement by ultrasonography has been studied to predict the success of extubation along with other standard extubation protocols. Till date only few studies have been done to show the correlation between diaphragm ultrasonography and successful extubation.

We did not have any studies utilizing diaphragm ultrasonography for weaning from mechanical ventilation at our institution. Hence, we did this study to evaluate the diaphragmatic thickening fraction (dTF) and diaphragmatic excursions (DE) along with the standard extubation protocol for successful extubation.

AIMS AND OBJECTIVES

PRIMARY OBJECTIVES:

1. To measure the diaphragmatic thickening fraction(dTF) and diaphragmatic excursion (DE) before and after spontaneous breathing trial (SBT).

2.To compare dTF and DE with standard extubation criteria in predicting extubation outcome.

SECONDARY OBJECTIVES:

1. To determine the incidence of readmissions to ICU

2. To determine the incidence of non-invasive ventilation following extubation**.**

ANATOMY OF THE DIAPHRAGM

INTRODUCTION

The diaphragm is a domed musculo fibrous sheet that separates the thoracic and abdominopelvic cavities. Mainly its convex superior surface faces the thorax, and its concave inferior surface is directed towards the abdomen. The positions of the domes or cupulae of the diaphragm are extremely variable and they are influenced by body build.[7]

Usually, after forced expiration, the right cupula is at the level anteriorly with the fourth costal cartilage and right nipple, whereas left cupula lies approximately one rib lower. On full inspiration, cupula will descend by as much as 10 cm, and on a plain chest radiograph the right dome coincides with the anterior end of sixth rib. The diaphragm lies more superiorly in the supine compared to the erect position.

ANATOMY

ATTACHMENTS:

- The diaphragm is joined to the body wall in a variety of ways. It is attached posteriorly to the upper lumbar vertebral bodies and discs by two diaphragmatic crura, which are linked by a fibrous median arcuate ligament.The paired medial and lateral arcuate ligaments are likewise included in the posterior attachments.[8,9]

- The anterior psoas muscles are covered by the medial arcuate ligaments. Fibrous attachments are also formed between the L1 or L2 vertebral body and the L1 transverse processes. The lateral arcuate ligaments are thicker fascial bands that run from the transverse processes of T12 laterally to the midportion of the 12th ribs, covering the quadratus lumborum muscle.

- The inferior sternum, xiphoid process, lower six ribs, and costal cartilage make up the diaphragm's anterior and lateral attachments. [10]

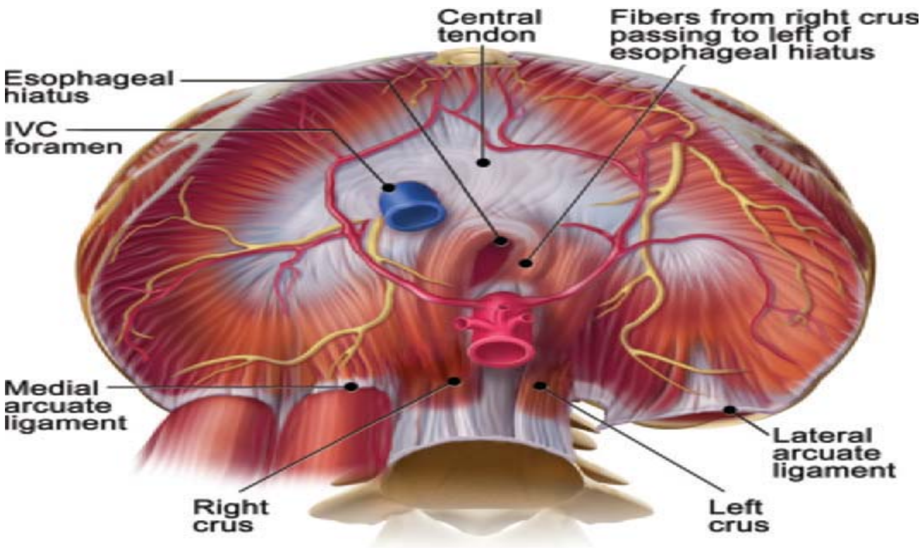


FIG 1: DIAGRAM SHOWING THE ATTACHMENTS OF DIAPHRAGM

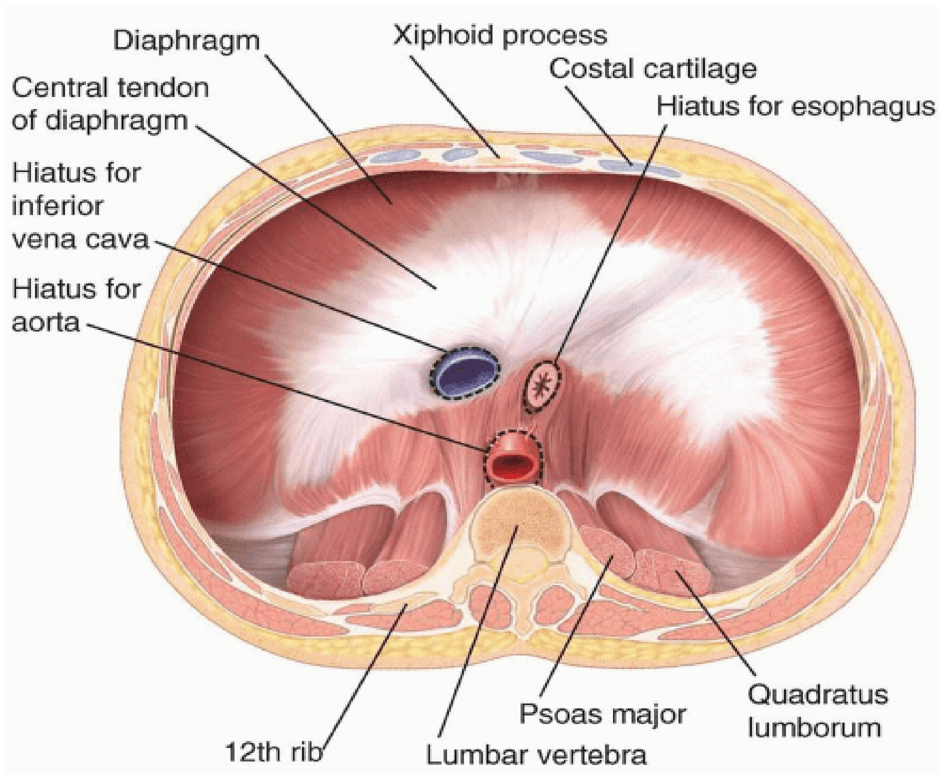
HIATUS:

Three primary openings in the diaphragm allow vital structures to pass between the thorax and abdomen.[9]

- The IVC hiatus, which is positioned at T8 level and contains the IVC as well as branches of the right phrenic nerve, is the first major opening. This then crosses through the central tendon's midpoint. With inspiration, the aperture will widen, allowing blood to flow into the heart.
- The esophageal hiatus, which is placed at the T10 level and contains the oesophagus, vagus nerve, and sympathetic nerve branches, is the second opening. This then goes through the right diaphragmatic crus muscle fibres, forming a ring around the oesophagus. Anatomically, the ring serves as a

sphincter. When we take a deep breath, it constricts and prevents gastroesophageal reflux.

- The aortic hiatus, which is located at the T12 level and contains the aorta, thoracic duct, azygos, and hemiazygos veins, is the third opening. This hiatus is not affected by frequent diaphragmatic contractions since it is retrocrural.



<u>FIG 2:</u> DIAGRAM SHOWING VARIOUS OPENINGS OF THE DIAPHRAGM

<u>EMBRYOLOGY</u>

Diaphragm Formation

1. Septum transversum

2. Pleuro-peritoneal membrane
3. Mesentery of esophagus
4. Mesoderm of the body wall

Insertion

The diaphragm inserts into a central tendon. The top surface of the tendon is partially connected to the lower surface of the fibrous pericardium.These muscular fibres that arise from the right crus cross along the left side and form a sling-like loop around the entrance of the oesophagus. These fibers act as a sphincter and likely assist in preventing the regurgitation of the stomach contents into the thoracic part of the esophagus.[11]

Origin of Diaphragm

Sternal

The sternal part originates as two fleshy slips from the back of xiphoid process.

Costal

The costal part originates from inner surfaces of the cartilages, adjacent parts of the lower sixth ribs on each side. It interdigitates with transversus abdominis.

Lumbar

The fascia covering the psoas major has a tendinous arch termed the medial lumbocostal arch. It attaches to the side of the body of vertebra L1 on the mediolateral side. It attaches to the front of the transverse process of vertebra L1 on the lateral side. The lateral lumbocostal arch is a tendinous arch in fascia covering the upper part of quadratus lumborum. Medially, they attach to the front of L1 vertebrae at the transverse process. Laterally, they connects to the lower border of 12th rib.

The anterolateral surface of the bodies of the upper three lumbar vertebrae, as well as the intervening intervertebral disc, give rise to the right crus.

The left crus arises from the corresponding parts of the upper 2 lumbar vertebrae.

Medial margin of two crura forms a tendinous arc across the front of the aorta called the median arcuate ligament.

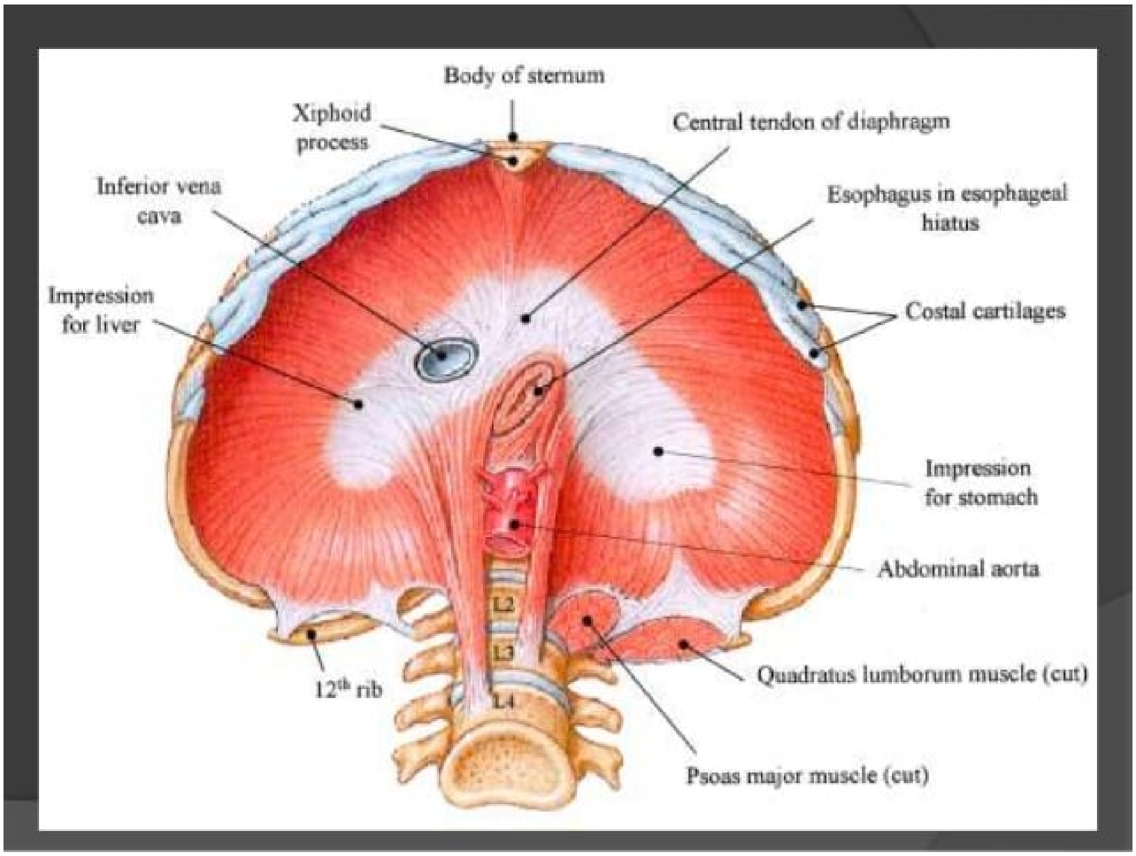


FIG 3: ORIGIN AND INSERTIONS OF THE DIAPHRAGM

Innervation

The right and left phrenic nerves, which originate from C3–C5 cervical nerves and facilitate both sensory and motor function, supply the diaphrgam. The lateral compartment of the neck contains the paired phrenic nerves, which travel anteriorly as they pass through the thorax.

Blood Supply and Lymphatics

Major Arteries Supplying the Diaphragm

The profuse arterial supply of the diaphragm is derived from anastomoses between the lower five intercostal and subcostal arteries, the superior and inferior phrenic arteries, and the pericardiacophrenic and musculophrenic arteries.

A) Intercostal and subcostal arteries

The lower five intercostal and subcostal arteries supply the costal margins of the diaphragm.

B)Inferior phrenic arteries

- The diaphragm's principal vascular supply comes from the right and left inferior phrenic arteries. The right side inferior phrenic artery usually starts from the celiac trunk or separately from the aorta, although it can also originate from the right renal artery, the left side of the gastric artery, or the hepatic artery itself.
- The left inferior phrenic artery normally develops from the celiac trunk or separately from the aorta, although it can also arise from the left renal artery, left gastric artery, or the hepatic artery proper on rare occasions.
- Each artery ascends anterolateral to the diaphragmatic crus, near the medial border of suprarenal gland. The left passes posterior to the oesophagus and then goes anteriorly on the far left of its diaphragmatic opening. The inferior right phrenic artery passes posterior to inferior vena cava, and then along the right side of its opening.

- Each phrenic artery divides into medial and lateral branches near the posterior border of the central tendon.
- The medial branch then curves anteriorly which anastomoses with its contralateral fellow anterior to the central tendon and also with the musculophrenic and pericardiacophrenic arteries.
- The lateral branch approaches the thoracic wall which anastomoses with the inferior posterior intercostal and musculophrenic arteries. The lateral branch of the right inferior phrenic artery supplies the inferior vena cava. The left sends ascending branches to the oesophagus.

C)Superior phrenic arteries

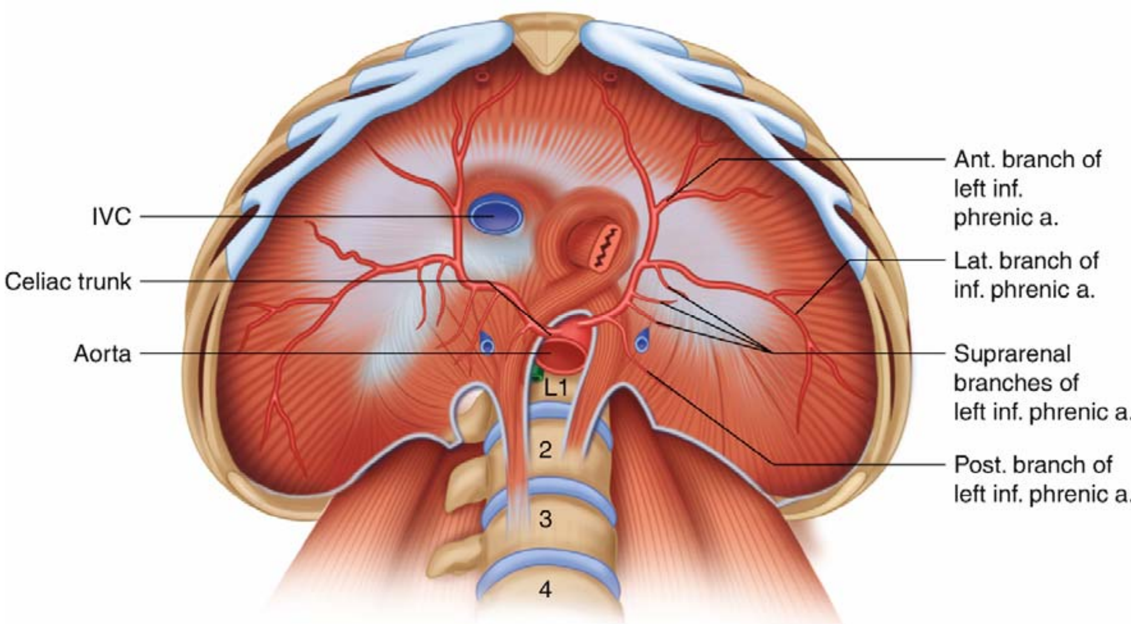
- These superior phrenic arteries supply the superior part of the diaphragm.
- The right superior phrenic artery arises from either the thoracic aorta, the proximal segment of the tenth intercostal artery or the distal segment.
- The left superior phrenic artery arises from the thoracic aorta or the proximal segment of the tenth intercostal artery; occasionally, it arises from the distal segment of the tenth intercostal artery

Venous drainage

Branches of the musculophrenic and pericardiacophrenic veins, which run alongside the respective arteries, drain the superior surface of the diaphragm. Both the right and left inferior phrenic veins have tributaries that drain the diaphragm's inferior surface.

- The right inferior phrenic vein feeds into either the inferior vena cava (usually always inferior to the diaphragm, but occasionally superior) or the right hepatic vein.

- The inferior vena cava — often inferior, but rarely superior to the diaphragm – drains the left inferior phrenic vein. It can also drain into the left suprarenal vein, left renal vein, left hepatic vein, or, on rare occasions, the left suprarenal renal vein and inferior vena cava.



<u>FIG 4</u>: ARTERIAL SUPPLY OF THE DIAPHRAGM

<u>FUNCTIONS:</u>

1. **Acts as a muscle of inspiration-** it contracts during the cycle and pulls the tendons down which increases the negative pressure that is inside the thoracic cavity and pulls in the air.

   During inhalation, diaphragm contracts and is pushed inferiorly into the abdominal cavity. The external intercoastal muscles raise the anterior chest wall like the handle of a bucket. It allows the chest to expand.

   During exhalation, relaxation and elevation of the diaphragm occurs which forces the air within the lungs to push out of the body.

2. **Muscles of abdominal straining:**

Contractions of the diaphragm will assist contracting of muscles of the abdomen that increases the intra-abdominal pressure with normal processes like parturition, defecation, micturition and for Valsalva maneuver.

3. **Thoracoabdominal Pump**:

   During inspiration the diaphragm goes down which decreases the intrathoracic pressure and increases the intraabdominal pressure. This causes the compression of inferior vena cava which moves the blood into the right atrium.

   - Valves in the thoracic duct prevents the backflow of lymph.

BASICS OF ULTRASOUND

One of the most widely used non-invasive imaging techniques in medical diagnosis is the ultrasound. Ultrasound is an interactive imaging technique in which the operator holds the ultrasound probe which is in the patient's contact and observes images of the internal anatomy in real time. [12]

In most instances, interpretation of the images is carried out simultaneously, rather than being reported by someone else at a later time.As this is radiation free, ultrasound is the preferred imaging modality in obstetric and paediatric investigations. It is most useful for imaging soft tissue anatomy and is widely used in the abdomen, pelvis, heart and neck. It has become a widely used imaging tool in musculo-skeletal investigations of muscles, tendons and joints. In addition to its well-established use in imaging soft tissue anatomy, ultrasound is a powerful tool in the study of blood flow in the veins and arteries, where use of the Doppler effect enables measurement of the blood velocity and it is also being used routinely in ICU for bed-side scans as well as for various assesments of the patients.

Standard ultrasound systems produce two-dimensional cross-sectional images of anatomy, but these may be extended to acquire data in three dimensions.

Ultrasound can be used safely in a variety of situations and its medical imaging has two aspects. First, ultrasound imaging involves depositing ultrasound energy in the patient that leads to some warming of exposed tissue. Hence minimizing such effects helps in obtaining a diagnosis. Second, perhaps a greater hazard is misdiagnosis. The risk of misdiagnosis must be controlled by ensuring that the ultrasound system is performing as intended and is operated competently. [13]

The detection and presentation of acoustic energy reflected from bodily interfaces is the foundation of all diagnostic ultrasound applications. These interactions offer the data required to build high-resolution gray-scale photographs of the body and to display blood flow statistics.Its unique imaging attributes have made ultrasound an important and versatile medical imaging tool. Some of the properties of Ultrasound are:

- Ultrasound is sound whose frequency is above the range of human hearing.
- Sound waves go through the body, then because the various internal structures reflect and scatter sound differently, returning echoes can be collected and used to form an image of the structure.
- Sound is characterized according to its frequency (number of mechanical variations occurring per unit time)
- Human audible range is 20-20000Hz

PROPERTIES

- Amplitude- strength/intensity of the wave(height of the wave)

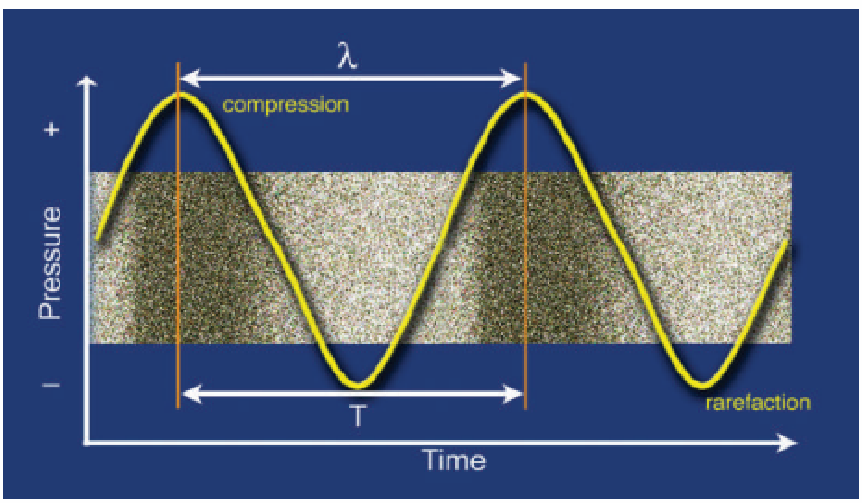
- Wavelength(lambda) – the distance between two consecutive, identical positions in the pressure wave (eg. Between two compressions or between two rarefactions)
- Frequency (f)- number of cycles per second (hertz) (1 hertz=1 cycle/sec)
- Period (T)- time taken for one complete cycle (1/f)
- Velocity- speed of the sound with direction specified.
- Speed of sound is a characteristic of each material through which sound travels eg;

a) Air- 330 meters/second

b) Metal-5000meters/second

c) Pure water- 1430 metres/second

d) Sound waves travels fastest in solids and slowest in gases.

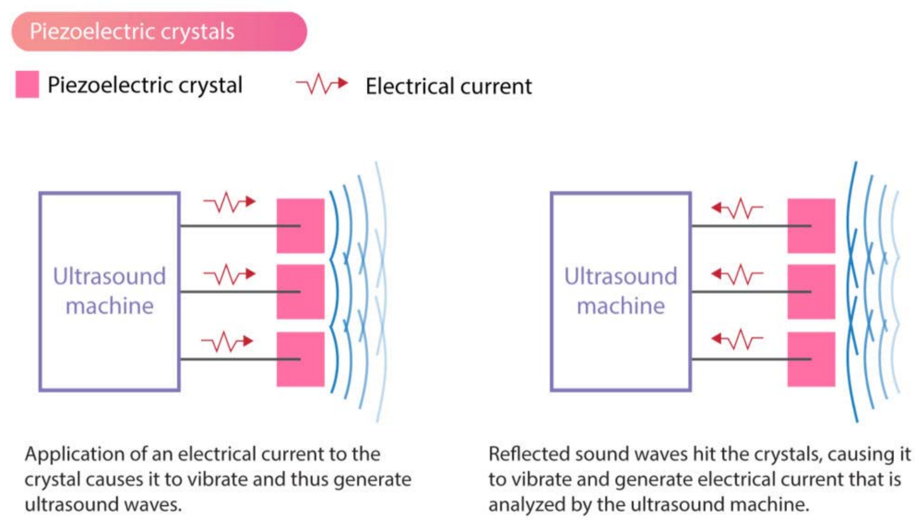


<u>FIG 5:</u> PROPERTIES OF THE ULTRASOUND WAVE

<u>PIEZOELECTRIC EFFECT:</u>

- Ability of a material to generate an electrical charge to applied pressure.

- When a piezoelectric material is compressed a potential difference is generated across opposite faces – one side positive and the other side negative. If an electrical field is applied it changes its shape.
- Ultrasound transducer works on the principle of piezoelectric effect.
- When voltage is applied to the faces of a crystal, it expands or contracts depending upon the polarity of the voltage applied. The crystal then resonates converting electricity to ultrasound.
- Conversely, when the crystal receives an echo, the sound deforms the crystal and a voltage is produced on its faces. This voltage is then analysed by the system.



<u>FIG 6:</u> DIAGRAM SHOWING THE PIEZOELECTRIC EFFECT

<u>TRANSDUCER ARRAY</u>

Arrangement of individual elements within the transducer. It can be classified as:

- Linear
- Curvilinear
- Phased

LINEAR ARRAY

- Large number of elements arranged in rows
- It produces parallel scan lines which are transmitted perpendicularly to the transducer face
- It has rectangular field of view.
- It has a flat transducer surface.

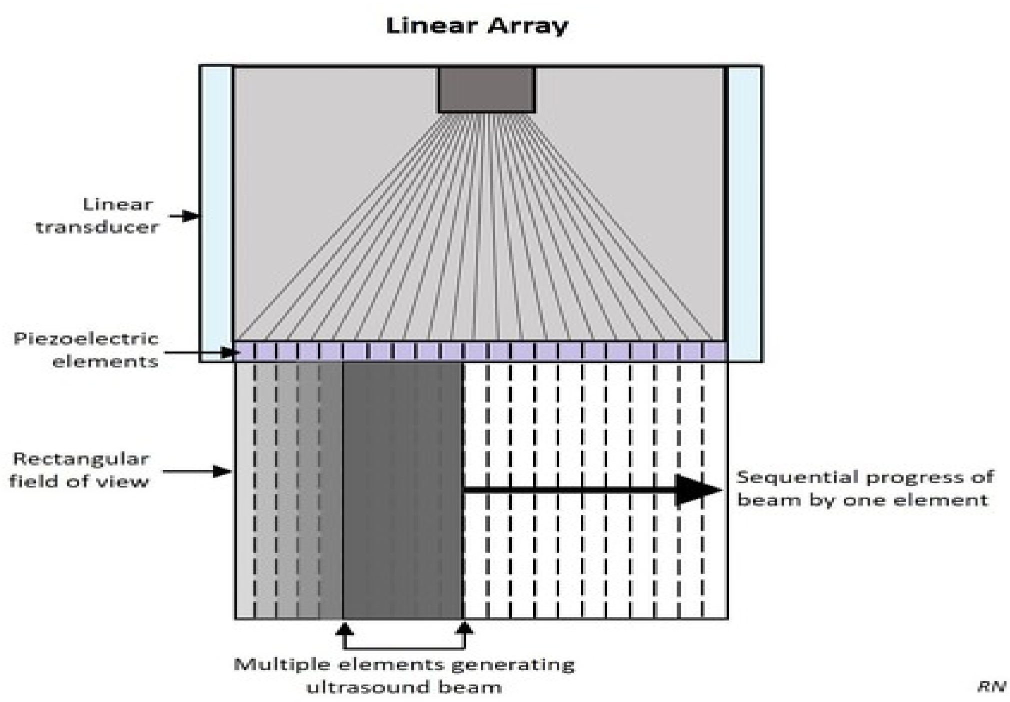
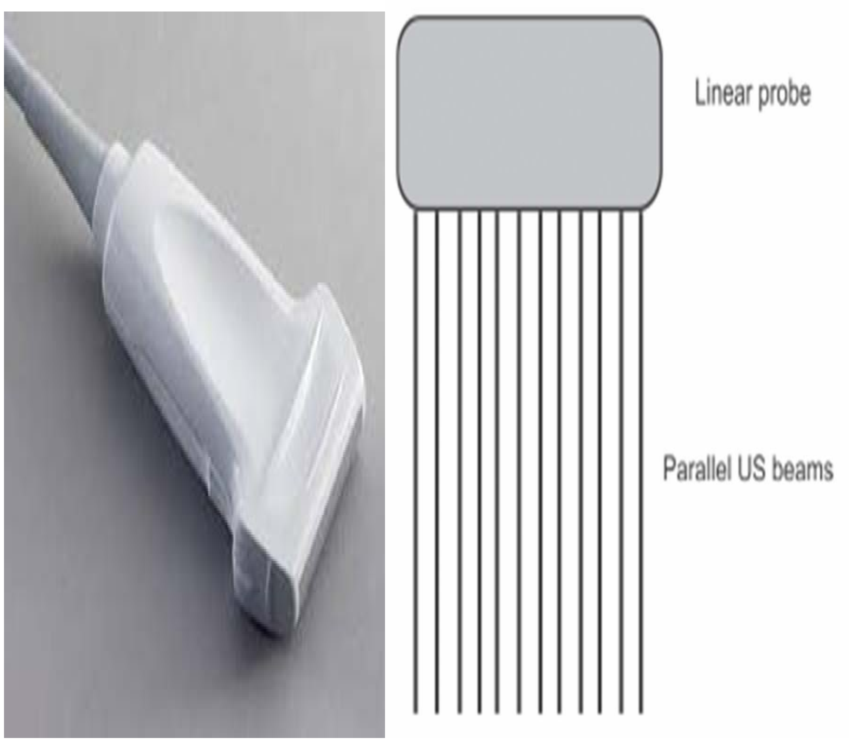


FIG 7: RAYS OF LINEAR ARRAY PROBE

Applications include:

- Small body parts like thyroid, testis
- Musculoskeletal imaging
- Vascular imaging
- Ultrasound guided biopsy
- Photoacoustic imaging, ultrasonic velocity change imaging
- Advantages are-precise anatomical details and good image quality across image depth and field of view.
- Disadvantages are limited field of view and depth
- For measurement of Diaphragmatic thickening fraction (dTF).
- 5-10Mhz frequency

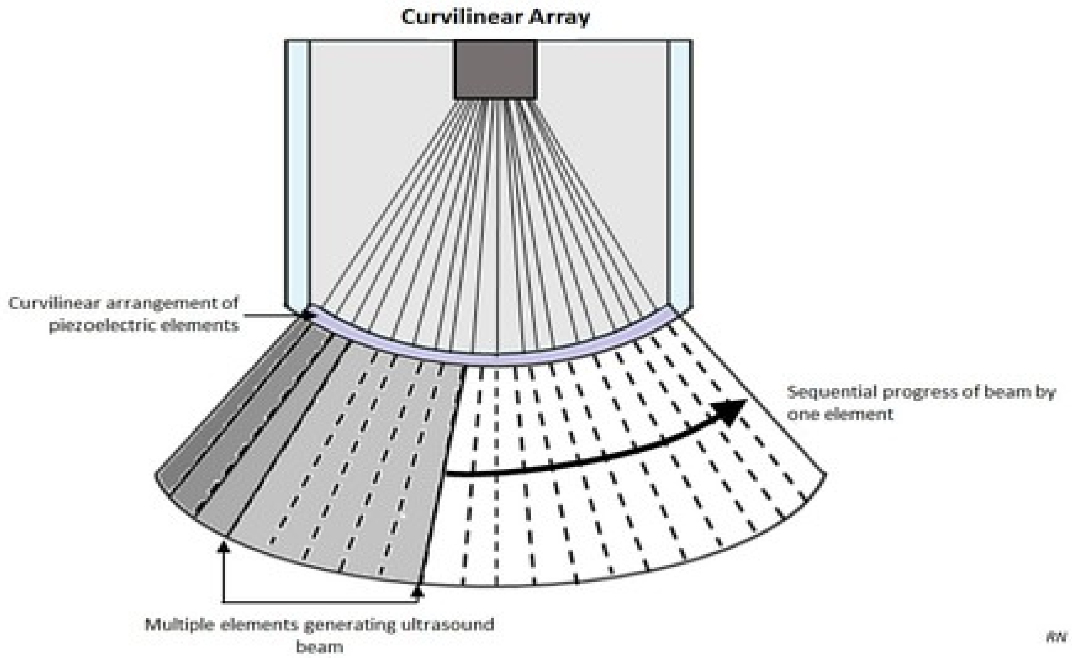


<u>FIG 8:</u> LINEAR PROBE

<u>CURVILINEAR OR CURVED ARRAY</u>

- It is designed with convex transducer surface which is used for sector scanning.
- It causes high penetration and has a big footprint.
- The beam is wider at depth and covers larger anatomy.
- It operates at 2-5MHz
- It can be used for abdominal, FAST, Lung scan, Pleura and gynaecological scans and for measurments of Diaphragmatic Excursion (DE).

FIG 9: CURVILINEAR PROBE



<u>FIG 10:</u> RAYS OF CURVILINEAR PROBE

<u>DISPLAY:</u>

- Scan converter creates 2D images from echo information
- Analog converters are unstable over time
- Digital scan converters are stable and allow image processing with variety of mathematical functions.
- Each pixel has a memory address that defines its location within the matrix.
- The image may be displayed as

  1.Bightness (B)-Mode

  2. Motion (M or TM)-mode

MOTION (M OR TM) -MODE:

- Another simple form of imaging, M-mode (motion-mode) ultrasound, displays echo amplitude and shows the position of moving reflectors. To indicate the intensity of the reflected signal, M-mode imaging uses the brightness of the display. The time base of the display can be adjusted to allow for varying degrees of temporal resolution, as dictated by clinical application.
- M-mode ultrasound is interpreted by assessing motion patterns of specific reflectors and determining anatomic relationships from characteristic patterns of motion.

USES:

1. Evaluation of fetal and embryonic heart rates and lung ultrasonography
2. Echocardiography, the rapid motion of cardiac valves and of cardiac chamber and vessel walls.
3. M-mode images may play a future role in the measurement of subtle changes in vessel wall elasticity accompanying atherogenesis.

BRIGHTNESS (B)-MODE

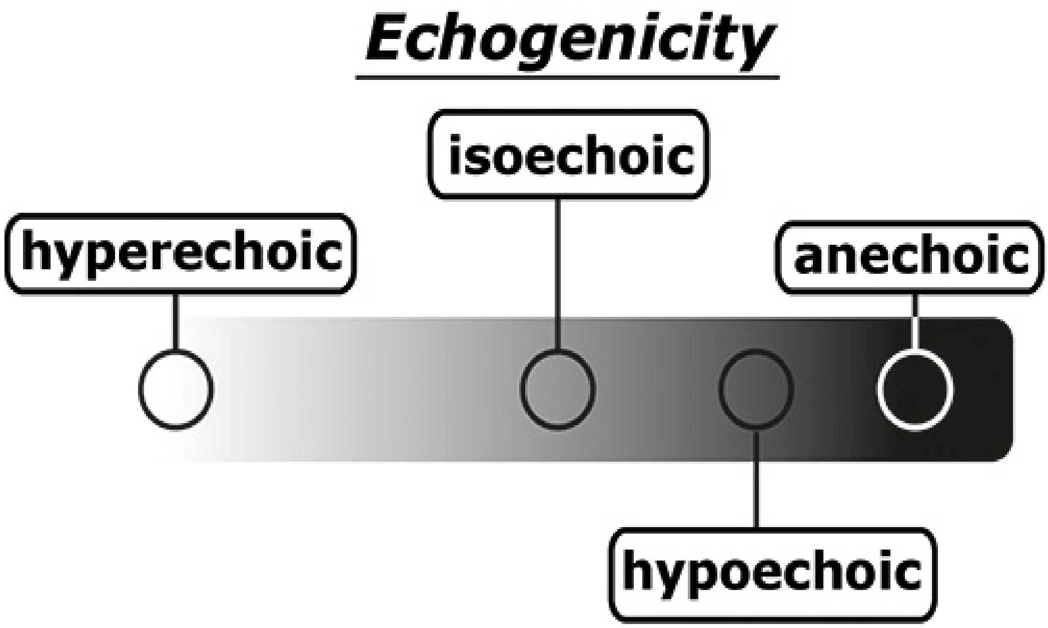
B-mode image is a cross-sectional image representing tissues and organ boundaries within the body.

- It is constructed from echoes, which are generated by reflection of ultrasound waves at tissue boundaries, and scattering from small irregularities within tissues. Each echo is displayed at a point in the image, which corresponds to the relative position of its origin within the body cross section, resulting in a scaled map of echo-producing features. The brightness of the image at each point is related to the amplitude or the strength of echo, giving rise to the term B-mode (brightness mode).

- To form a B-mode image, a source of ultrasound, the transducer, is placed in contact with the skin and short bursts or pulses of ultrasound are sent into the patient. These are directed along narrow beam-shaped paths. As the pulses travel into the tissues of the body, they are reflected and scattered, generating echoes, some of which travel back to the transducer along the same path, where they are received. These echoes are used to form the image.
- The transducer is moved back and forth, so that beam scans a 2D section of the patient.
- It maybe a linear or sector scanning.
- Echoes are displayed as dots and brightness is proportional to echo intensity.
- Thousands of echo signal strengths of varying brightness of points gives grey scale image.

USES:

1. Image guided injections for needle placement or any aspiration procedure
2. Identification of lesion, cysts or tumors.
3. Locating any structural anomalies
4. Visualizing cardiac and vascular movement across the cardiac cycle.



Tissue Type	Echogenicity
Bone	Hyperechoic
Tendon	Hyperechoic
Ligament	Hyperechoic
Nerve	Hyperechoic/Hypoechoic
Muscle	Hyperechoic lines/hypoechoic background
Fat	Hypoechoic
Vascular structure (ie, arteries, veins)	Anechoic
Cyst	Anechoic

[a] A hyperechoic image is bright (ie, white), a hypoechoic image is darker (ie, gray), and an anechoic image is completely dark (ie, black).

<u>FIG 11:</u> DIFFERENT ECHOGENIC STRUCTURES

WEANING FROM MECHANICAL VENTILATION

Successful weaning is defined as absence of any form 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 can be used to support and maintain adequate spontaneous ventilation and oxygenation.[14]

TABLE 1: STANDARD CRITERIA FOR EXTUBATION

CATEGORY	EXAMPLE	NOTE
CLINICAL CRITERIA	• Resolution of acute phase of disease • Adequate cough • Absence of excessive secretions • CVS and Hemodynamic stability	
VENTILATORY CRITERIA	Spontaneous Breathing Trial PaCO2 Vital Capacity Spontaneous Vt Spontaneous f f/Vt Minute Ventilation	Tolerates 20 to 30 min <50 mmHg with normal pH >10ml/kg >5ml/kg <35/min <100bpm <10L with satisfactory Abg
OXYGENATION CRITERIA	PaO2 without PEEP PaO2 with PEEP(<8cm h20) SaO2 PaO2/FiO2	>60mm Hg at FiO2 upto 0.4 >100mm Hg at FiO2 upto 0.4 >90% at FiO2 upto 0.4 >150mm Hg
PULMONARY RESERVE	Vital Capacity	>10ml/Kg
PULMONARY MEASURMENTS	Static Compliance	>30ml/cm H2o

SPONTANEOUS BREATHING TRIAL:

One of the most significant test to determine if patients can be successfully extubated and weaned from mechanical ventilation is the spontaneous breathing trial test. Low level pressure support (PS), continuous positive airway pressure (CPAP) may be used along with SBT.[15]

When the decision to wean is reached, the patient is taken off of complete ventilatory support and placed on a spontaneous breathing mode for up to 30 minutes via the ventilator or T-Piece.Oxygen and low pressure support is used to supplement oxygenation and augments spontaneous breathing.

Criteria for SBT:

1. Normal Respiratory Pattern (absence of rapid shallow breathing)
2. Adequate gas exchange
3. Hemodynamic stability

STEPS OF SBT:

1. May use T-piece or CPAP
2. Let patient breathe spontaneously for upto 30min
3. May use low level pressure support (upto 8cm H20 for adults and 10cm H20 for peadiatrics) to augment spontaneous breathing
4. Assess patient
5. If patient tolerates step 4, consider extubation when blood gases and vital signs are satisfactory.
6. Return patient to mechanical ventilation to rest if necessary.

SBT FAILURE:

1. PaO2<60mm Hg on FiO2>50%
2. SaO2 <90% on FiO2 >50%
3. PaO2 > 50mmHg or an increase in PaCO2 > 8mm Hg from baseline of SBT
4. pH <7.32
5. f/Vt > 100 breaths per min per litre
6. f>35 breaths per min or increase by >50% from baseline SBT
7. Heart Rate >140 beats per minute or increase by >20% from baseline SBT
8. Systolic BP >180mm Hg or increase by >20% from baseline of SBT
9. Systolic BP <90mm Hg
10. Presence of cardiac arrythmias

ULTRASONOGRAPHY OF THE DIAPHRAGM

INTRODUCTION

In recent years and due to development of new advances, diaphragmatic ultrasonography has become an effective tool in the evaluation of diaphragm function for weaning from mechanical ventilation. It is a safe, effective, no-radiation, bedside tool and can be used to obtain multiple values. Ultrasonography is a promising tool for assessing the anatomy and dynamic activity of the diaphragm, and it is the modality of choice for evaluating any diaphragm paralysis, particularly in neonates, children, and critically ill patients. [16]

Diaphragmatic dysfunction among patients hospitalized in the intensive care unit (ICU) is commonly attributed to critical illness and is associated with polyneuropathy and myopathy. [17]

Patients that are subjected to mechanical ventilation, even after a short period of time, can have diaphragmatic dysfunction that is caused by these ventilators by reducing the force that generates the capacity of the diaphragm, which may cause further weaning difficulty. The diaphragmatic dysfunction can be worsened further by disuse atrophy of both fast-twitch and slow-twitch myofibers of the diaphragm after the administration of a neuromuscular blocking agent [18,19,20]

The routine parameters that are used for standard extubation are the correction of underlying pathological conditions, stable haemodynamic parameters, Spo2, respiratory rate, minute ventilation, RSBI and also the assessment of GCS. These criteria's are used in basic ICU set up for weaning any patient from mechanical ventilation.

Alongwith these parameters, assessment of diaphragm functions like diaphragmatic thickening fraction and diaphragm excursion can also be done for aiding in decision making for extubation. The decision for extubation cannot be soley made on only one parameter, hence in recent advances the values of these diaphragm measures are obtained to help come to a conclusion regarding the extubation.

Neither are there any particular guidelines nor as there any criteria to choose the best time to start weaning and for reduction of the supports. The patients' readiness to wean off from ventilator was assessed daily by a series of clinical judgment made by the attending intensivist and or the physician. The primary physicians were then blinded to the results obtained by the ultrasound. The research team did not play a role in deciding whether a patient will be extubated or not.

Bedside ultrasound is being increasingly performed for real-time assessment of diaphragmatic movement. This technique allows qualitative and quantitative assessment of diaphragmatic function in terms of dTF and DE during contraction, which help to diagnose diaphragmatic weakness and respiratory workload in patients in the ICU.[21,22,23,24,25]

- DTF and DE during respiration reflect diaphragm function and are similar to "thickening fractions and motion amplitude" of the heart. Diaphragm thickness measured at end inspiration correlates with maximal inspiratory pressure and the change in diaphragm thickness during respiration is strongly related to lung volume.[26,27]
- Diaphragmatic ultrasound is a useful technique to evaluate the anatomy and function of the diaphragm, specifically diaphragmatic excursion and thickening.
- The ultrasound system should be equipped with a 2-5 MHz curvilinear transducer and a 7-10 MHz linear transducer.

On ultrasound, the diaphragm can be explored through two acoustic windows: over the subcostal area (SCA) and over the zone of approximation (ZOA). Through the SCA window, ultrasound shows the diaphragm as a deeply located curved structure that separates the thorax from the abdomen (Figure A).Through the ZOA window, the diaphragm is identifiable as a three-layer structure (Figure D)consisting of one hypoechoic inner muscle layer surrounded by two hyperechoic outer membranes (the peritoneum and pleura)[23],[28-30]

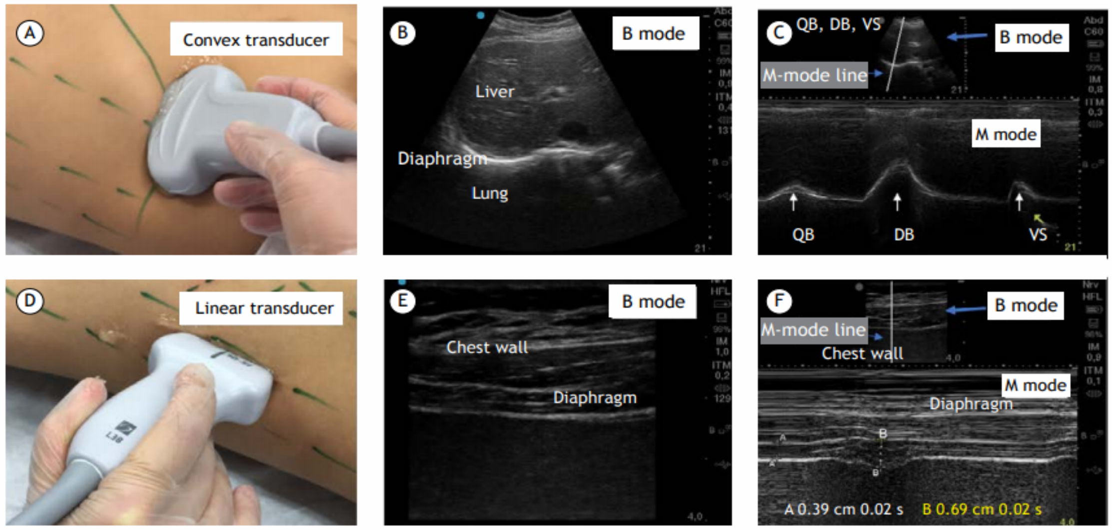


FIG 12: HOLDING OF THE PROBE TO CAPTURE DE AND DTF

DIAPHGRAMATIC EXCURSION

- DE measures the distance that the diaphragm is able to move during the respiratory cycle. It measures the amplitude of the diaphragmatic dome movements.
- Normal diaphragmatic thickness ranges from 3cm on both sides but lower value can be taken as 1.5 cm in both the gender. [31]
- The measurement is performed either in a subcostal or intercostal approach in the mid-clavicular line or in the right or left anterior axillary line.

TECHNIQUE:

- DE is measured with a low frequency phased-array or curved-array. It is also called an abdominal probe with a frequency of 2-5MHz, positioned just at the subcostal region or the costal arch.
- It is placed between the mid-clavicular and the mid-axillary line, assessed in the right or the left sagittal plane in the B-Mode.
- Operator should look for individual hemidiaphragm through the hepatic or the splenic window.
- Patient should be placed in the semi-seated position and probe should be angled as much as cranio-caudally as possible.

MEASURMENTS IN MODES:

- ✓ In B-Mode, right and left hemidiaphragm both can be seen, hence it allows the comparison of both the excursions
- ✓ Right Hemidiaphragm appears as a thick, curving and hyperechoic line.
- ✓ Transducer is placed medially, cranially and dorsally so that the ultrasound beam reaches the posterior third of the right hemidiaphragm. [32,33]
- ✓ Excursion is quantified in the M-Mode, with M-line placed perpendicular to the direction of the motion, to obtain maximum excursion.[32,33,28]
- ✓ It is measured by placing the calipers at the bottom and the top of the diaphragmatic inspiratory slope.
- ✓ It is measured from M-Mode during inspiration and expiration.
- ✓ During inspiration, the first caliper is placed at the foot of slope of diaphragmatic echoic line and second is placed at the apex.
- ✓ During expiration, same measurements can be performed between beginning and end of the expiratory slope.

FORMULA= Movement during inspiration- movement during expiration.

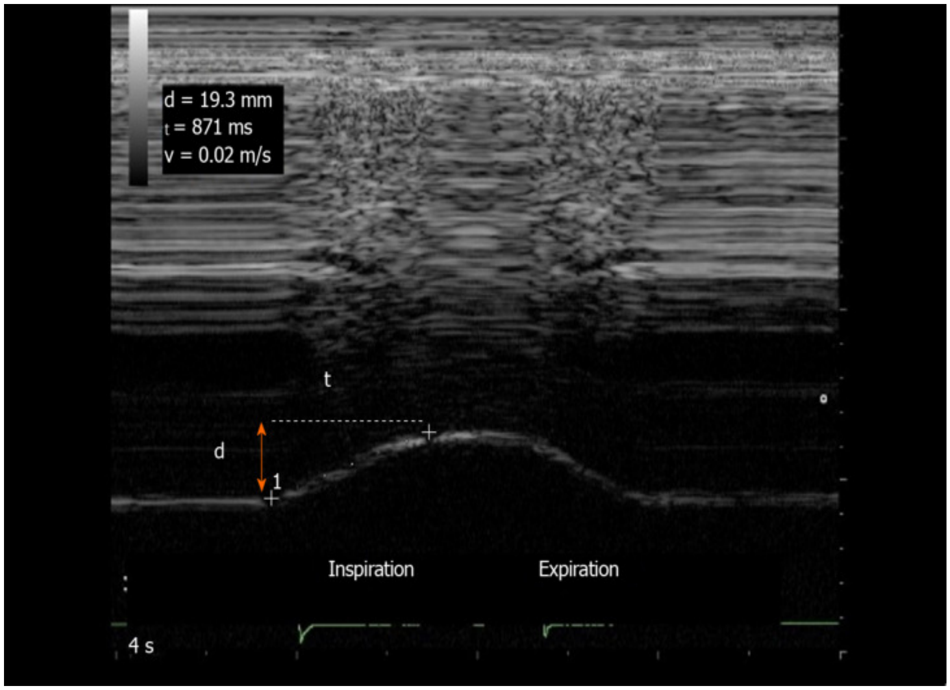


FIG 13: M-MODE PICTURE OF DIAPHRAGMATIC EXURSION

DIAPHRAGMATIC THICKENING FRACTION

- Ultrasound can assess the percentage change in the diaphragmatic thickness from expiration to inspiration. (dTF). It is also used to assess the atrophy and contraction of the diaphragm.
- Normal value is usually taken above 35% and above.[31]
- It is measured using a linear array transducer of high frequency of 7-10MHz, positioned in the cranio-caudal direction, below the costo-phrenic angle in the B-Mode.

- The probe is positioned perpendicular to the skin in the zone of apposition between the mid-axillary or the antero-axillary line, in the 8-10th intercostal spaces.[25,34]

TECHNIQUE:

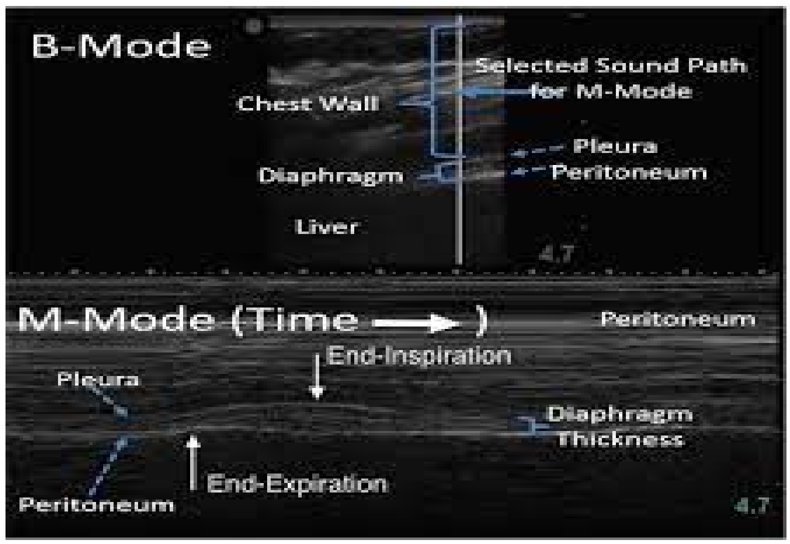
- dTF is measured using a high frequency linear probe. As an appropriate procedure, the probe should be angled perpendicular to the chest wall.
- It should be placed below the phrenico-costal sinus near the anterior or the mid-axillary line between the 8th to 10th intercoastal space.
- It is usually done by moving the probe from anterior axillary line to the mid axillary line.
- These measurements are taken with patient in semi-decubitus position (30 degree head end elevation)

MEASURMENTS IN MODES:

- In the B-Mode , the diaphragm is identified as a hypoechoic line which comes as a inner muscular layer bounded by the two hyperechoic membranes, namely the pleural (superficial line) and the peritoneum (deeper line).
- The third hyperechoic line is frequently seen in the middle of the non-echogenic layer.
- Once this line has been identified properly and clearly it is then shifted onto the M-mode.

- dTF can be measured as the distance from the middle of the pleural membrane to the middle of the peritoneal membrane 35,28,36,23,37
- Thickening fraction of diaphragm is calculated in the M-Mode as the percentage inspiratory increase in the diaphragm thickeness relative to the end expiratory thickeness during tidal breathing.

FORMULA: dTF= [Tinp-Texp)/Texp]*100



<u>FIG 14</u>: M-MODE PICTURE OF DIAPHRAGMATIC THICKENING FRACTION

REVIEW OF LITERATURE:

- **DiNino E, Gartman E, Sethi J, McCool D. in 2014** determined that using pressure support and spontaneous breathing attempts, ultrasonography assessments of diaphragm muscle thickening might predict extubation success or failure, and that this could be especially useful in minimising the frequency of failed extubations..[2]
- **Criner G in 2014** advised emphasising the potential use of dynamic performance information that real-time ultrasonography measurement of the diaphragm and heart functions could provide to clinicians in predicting weaning results.[1]
- **Ali E, Mohamad A in 2016** noticed that there was increasing weakness in patients with mechanical ventilation and was found the contributing cause of weaning failure. Hence they did the study to measure diaphragm thickness and excursion measured by ultrasonography as a predictor for weaning outcome and the cut off was taken >30% for dTF and >1.5cm for DE.[38]
- **Hasan A.A, Farghaly S in 2017** did a study in forty-four patients who successfully passed spontaneous breathing trial (SBT). These patients were assessed by ultrasound during SBT for evaluation of diaphragmatic thickening fraction and diaphragmatic excursion. It was concluded that the ultrasound evaluation of diaphragmatic thickening fraction and diaphragmatic excursion could be a good predictor of extubation in those patients who passed SBT. [39]

- **Hayat A, Khan A, Khalil A, Asghar A in 2017** concluded thatultrasonography measurement of diaphragmatic excursion is a good method for predicting weaning outcome from mechanical ventilation.[40]

- **Li C,Li X,Han H, Cui H, Wang G in 2018** concluded thatdiaphragm ultrasonography maybe a reliable, non-invasive and convenient way to predict re-intubation within 48hours of extubation.[3]

- **Qian Z, Yang M, Li L, et al in 2018**did eleven studies involving a total of 436 patients. There were eight studies comparing diaphragmatic excursion (DE), five comparing the diaphragmatic thickening fraction (DTF) and two comparing Diaphragmatic dysfunction between the groups with and without successful weaning. Both DE and DTF showed good diagnostic performance to predict weaning outcomes in spite of limitations included high heterogeneity among the studies.[41]

- **TurtonP, ALAidarous S and Welters I in 2019** showeddifferent methods of diaphragmatic function assessment using ultrasonography to predict weaning from mechanical ventilation.[42]

- **El Naggar TA, Dwedar IA, Abd-Allah EF in 2019** did a study on 41 patients who received the conventional measurements for weaning and transdiaphragmatic ultrasonography after extubation. They assessed the diaphragmatic mobility and diaphragmatic thickening fraction. All the ultrasonography findings were gathered and compared with some of the usual tools such as ABG. It was concluded that the diaphragmatic ultrasonography could be used as a new tool for prediction of weaning process.[43]

- **Fahmy H, Saied M, Sayed I, Kinawy S in 2019** did a study to evaluate the role of the diaphragm and lung ultrasonography principally (DE,dTF and LUS scores) in prediction of the extubation outcome from mechanical ventilation. It was concluded that the integration of dTF>30% of the right hemidiaphragm with LUS <12 improved the expectation of successful extubation in comparison with dTF % alone.[44]
- **Dalia A, Rahman A, Saber, S & El-Maghraby A in 2020**This prospective study was conducted in 106 mechanically ventilated children aged between 1 months to 170 months were included in the study. All these patients were candidates for weaning and have been given a chance for spontaneous breathing trial (SBT), during which diaphragmatic and Lung Ultrasound was performed for them and it was concluded that diaphragmatic and lung Ultrasound add a quick, accurate and non-invasive indices to the weaning readiness parameters compared to the other standard parameters alone. So, it is recommended to be added to the predictive parameters of weaning outcome.[45]
- **Dhochak. N, Lodha R in 2020** concluded that ultrasound could be used as a non-invasive bedside tool to assess diaphragmatic function and lung parenchyma status in critically ill children. Ultrasound can assess percentage change in diaphragmatic thickness from expiration to inspiration (diaphragmatic thickening fraction, DTF) and amplitude of diaphragmatic dome movements in respiratory cycle (diaphragmatic excursion, DE) which are indicators of strength of diaphragmatic contractions.[46]
- **Elshazly M, Kamel K, Elkorashy R, Ismail M,Ismail J, Assal H in 2020** included 62 patients who were on mechanical ventilator from the chest intensive care unit in this study. Sixty-two patients who successfully passed

the spontaneous breathing trial (SBT) in this test were enrolled. The transthoracic ultrasound of the diaphragm was performed during an SBT to the assess diaphragmatic function (excursion and thickness), and they were classified into the successful extubation group and the failed extubation group.The diaphragmatic excursion cut-off value predictive of weaning was 1.25 cm, with a specificity of 82.1% and a sensitivity of 97.1% respectively, and the diaphragmatic thickness cut-off value predictive of weaning was 21.5%, with a specificity of 60.7% and a sensitivity of 91.2%, respectively and it was concluded that the diaphragmatic ultrasonography can be a promising tool for predicting the extubation outcome for mechanically ventilated patients.[47]

- **Bahgat E, El-Halaby H, Abdelrahaman A, Nasef N, Abdel-Hady H in 2021** observed that sonographic assessment of diaphragmatic thickness and excursion was found to be an accurate tool in predicting successful extubation of adult patients from invasive mechanical ventilation. It was concluded that diaphragmatic excursion is a useful indicator for successful extubation of preterm infants from mechanical ventilation.[48]
- **Gok F, Mercan A, Kilicaslan A, Sarkilar G, Yosunkaya A in 2021** did a study on 62 patients with an aim to investigate predictive values of diaphragmatic thickening fraction (dTF) and diaphragmatic excursion (DE) and anterolateral lung ultrasound (LUS) scores in extubation success and compare with RSBI. Cut off values were taken as 27.5% for dTF and 1.3cm for DE and concluded that investigating the lung and diaphragm via ultrasound provides real time information to increase extubation success.[49]

- **Varón-Vega F et all in 2021** did a study on 84 patients to evaluate diaphragmatic excursion (DE), inspiration time, diaphragm contraction speed and diaphragmatic thickening fraction (dTF) were evaluated at the end of spontaneous ventilation. It was concluded that ultrasound could be a part of a multifactorial approach in the extubation process.[50]

MATERIALS AND METHODS:

This was a prospective, double blind observational study.

SOURCE OF DATA:

This study was conducted on 41 patients [2] admitted in ICU requiring mechanical ventilation and satisfying the inclusion criteria at R. L. Jalappa Hospital and Research centre, Tamaka, Kolar, in the period from January 2020 to May 2021.

- Study Design: Double blind observational study
- Sample Size: 41
- Duration of study: From January 2020 to May 2021.
- Sampling Method: Simple Random Sampling

METHOD OF COLLECTION OF DATA:

- Number of patients was 41
- Informed consent was taken from the patients's attenders
- Result values was recorded using a Performa

INCLUSION CRITERIA

Patients more than 18 years of age on mechanical ventilation for respiratory failure and appropriate for weaning onto pressure support ventilation.

EXCLUSION CRITERIA

1. Spinal cord injury
2. Arrhythmias and haemodynamic instability.

3. Pneumothorax, pneumomediastinum, thoracotomy, chest tube, chest injuries that prevent ultrasound.
4. Pleural lesions or pleurodesis.
5. Pregnancy
6. Poor ultrasound image.

RESEARCH QUESTION:

Can ultrasound measurments of the diaphragm thickening fraction and diaphragmatic excursion during inspiration provide a measure of extubation success or failure?

- Successful extubation- defined as spontaneous breathing>48hours following extubation.
- Failed extubation- defined as someone who was re-intubated within 48 hours of extubation.

HYPOTHESIS:

Measuring dTF and DE using ultrasonography increases the chances of successful extubation.

NULL-HYPOTHESIS

Measuring dTF and DE using ultrasonography will not reduce the chances of successful extubation.

SAMPLING PROCEDURE :

Patients were included in the study after obtaining written, informed consent taken from the patient's next of kin. This study was conducted on adult patients more than 18 years of age requiring mechanical ventilation for any respiratory failure and appropriate for weaning onto pressure support ventilation from Jan2020-May2021

Necessary investigations like blood haemoglobin and Arterial blood gas (ABG) were done prior to subjecting the patient for pressure support ventilation and ABG was done immediately before extubation.

In this study, we divided doctors into the treating team and the research team. Treating team included the primary doctors working in ICU and they evaluated the patient's readiness for the pressure support ventilation. The research team did the diaphragm ultrasonography in those patients who satisfied the inclusion criteria. The treating team were blinded to dTF and DE results of the research team.

Prior to extubation, all the patients had to satisfy the standard extubation criteria followed at RLJH, kolar.

Standard extubation criteria included 2 hours of pressure support ventilation with PEEP of 5 and pressure support of 8. It also includes respiratory rate <30, exhaled tidal volumes (>6ml/kg ideal body weight), RSBI (<105), and leak test (>100ml difference of tidal volumes).

The research team scanned the diaphragm for dTF and DE twice before extubation. First scan was done immediately prior to subjecting the patient to pressure support ventilation and the second scan was done prior to extubation.

In the diaphragm ultrasound examination, we measured dTF using 7-10MHz, linear probe was in M-mode on the anterior to mid-axillary line between 8^{th} and

10th intercoastal space. Diaphragmatic excursion was measured in the mid clavicular line using 2-5MHz, curvilinear probe was in M-mode during the respiratory cycle.

Both these measurments are taken with patient in semi-decubitus position (30 degree head end elevation)

The sonographer captured 3 measurments, each time and the mean of 3 values was taken and incorporated into the formula:

dTF of diaphragm= (Inspiratory thickness of diaphragm-Expiratory thickness of diaphragm/Expiratory thickness of diaphragm)*100.

dTF anything above 35% was considered for weaning.

Diaphragm excursion:

Measured the distance that the diaphragm was able to move during the respiratory cycle.

Diaphragm excursion(DE) = movements of diaphragm during inspiration-movement of diaphragm during expiration.

DE anything between 2-5cm was considered as to be normal and above 1cm was taken for extubation.

PARAMETERS OBSERVED:

1) ABG

2) Respiratory rate

3) RSBI

4) Exhaled tidal volume

5) Leak test

STATISTICAL METHODS

Proportion- Absolute Precision

Expected Proportion- 0.88

Precision (%)= 10

Desired confidence level (%) = 95

Required sample size= 41

FORMULA:

$$n = \frac{Z^2_{1-a/2}\, p(1-p)}{d^2}$$

Where,

p= Expected proportion

d=Absolute proportion

1-a/2=Desired confidence level

STATISTICAL ANALYSIS:

Collected data was coded and entered into an excel data base. All the quantitative measures were presented by (mean $\pm$SD) and confidence interval, qualitative measures by proportions and CI. Sensitivity, specificity, PPV, NPV and ROC and AUC analysis were used. The significance of difference in proportions was done using Chisquare test/ Fisher's Exact test. P value < 0.05 was considered to be as statistically significant.

OBSERVATION AND RESULTS

TABLE 2: AGE DISTRIBUTION OF THE PATIENTS STUDIED

Age in years	No. of patients	%
20-30	13	31.7
31-40	2	4.9
41-50	7	17.1
51-60	7	17.1
61-70	7	17.1
>70	5	12.2
Total	**41**	**100.0**

Mean ± SD: 47.68±18.89

The observation of the above study showed maximum number of subjects were in the age group of 20-30years accounting to 31.7%(13 out of 41). The next common age group being in 41-70 years accounting to 17.1%.

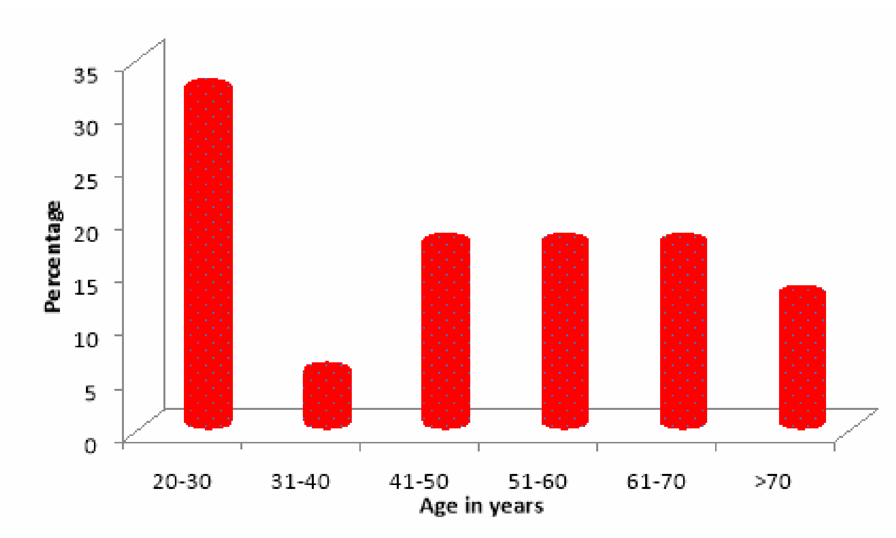


FIGURE 15: BAR GRAPH SHOWING AGE DISTRIBUTION OF THE PATIENTS STUDIED

TABLE 3: GENDER DISTRIBUTIONS OF THE PATIENTS STUDIED

Gender	No. of patients	%
Female	13	31.7
Male	28	68.3
Total	**41**	**100.0**

The study with total sample size of 41, 28(68.3%) subjects were males and 13(31.7%) were females showing male predominance.

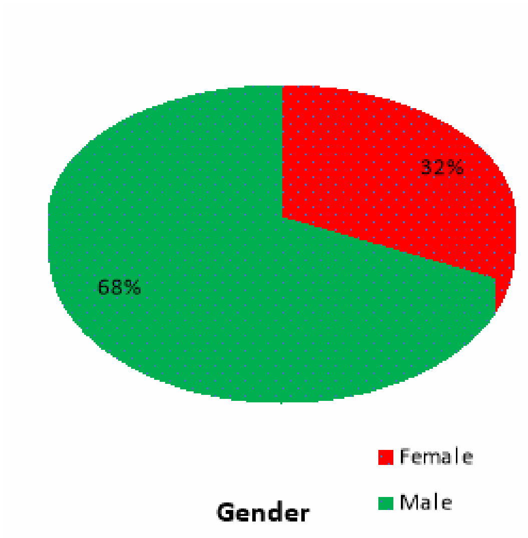


FIGURE 16: PIE CHART SHOWING GENDER DISTRIBUTION OF THE PATIENTS STUDIED

TABLE 4: WEIGHT (KG)-FREQUENCY DISTRIBUTION OF PATIENTS STUDIED

Weight (kg)	No. of patients	%
<50	3	7.3
50-60	12	29.3
61-70	12	29.3
71-80	14	34.1
Total	**41**	**100.0**

Mean ± SD: 63.51±9.99

Among weight distribution 14 patient(34.1%) were in the 71-80kg with next common being in 50-70kg accounting to 12 patients(29.3%) each.

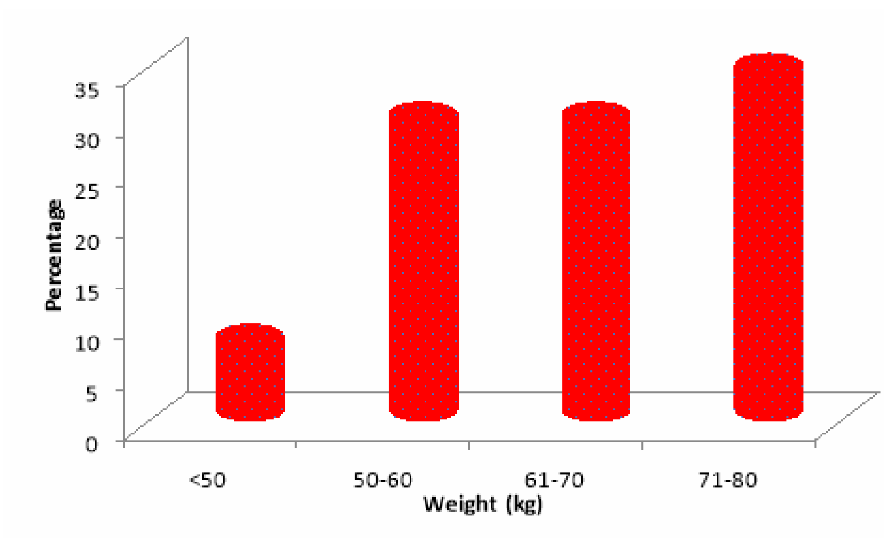


FIGURE 17: BAR GRAPH SHOWING WEIGHT(KG) FREQUENCY DISTRIBUTION IN PATIENTS STUDIED

TABLE 5: ABG- ASSESSMENT PRIOR TO PS AND PRIOR TO EXTUBATION OF PATIENTS STUDIED

ABG	Prior to PS	Prior to extubation	Difference	t value	P value
Ph	7.40±0.10	7.44±0.07	-0.038	-2.458	0.018*
PaO2	120.76±48.55	126.32±58.74	-5.561	-0.663	0.511
FIO2	41.83±8.86	35.49±1.87	6.341	4.575	<0.001**
PaCO2	37.95±14.21	34.71±7.25	3.244	1.657	0.105

From the above table in the ABG analysis values taken prior to Pressure Support and Prior to Extubation it was found that FiO2 value was considered to be strongly significant with P value<0.001 and next most significant was the pH value with a P value of 0.018.

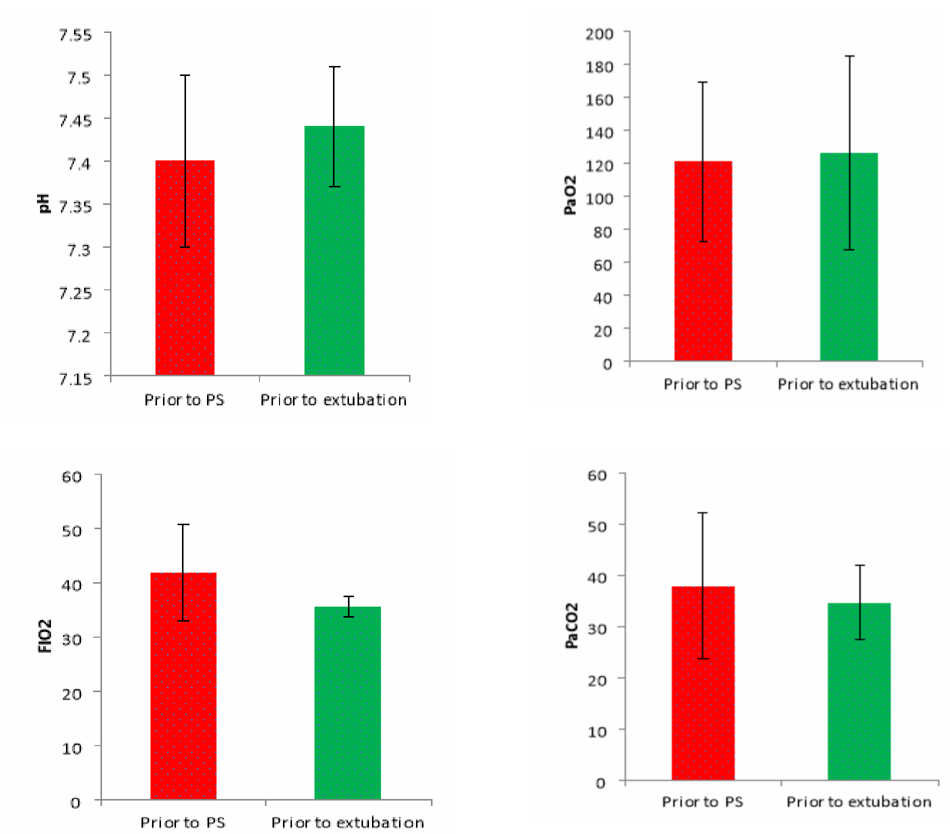


FIGURE 18: BAR GRAPH SHOWINGABG- ASSESSMENT PRIOR TO PS AND PRIOR TO EXTUBATION OF PATIENTS STUDIED

TABLE 6: RSBI

RSBI	No. of patients	%
20-30	17	41.5
31-40	15	36.6
41-50	9	21.9
Total	**41**	**100.0**

This table shows the rapid shallow breathing index(RSBI) of the 41 patients studied. RSBI is considered normal if the value is <105. Lower the RSBI value, better the chances for extubation and in this study it was found that majority of the patients that is 17 patients (41.5%) had RSBI between 20-30bpm/L.

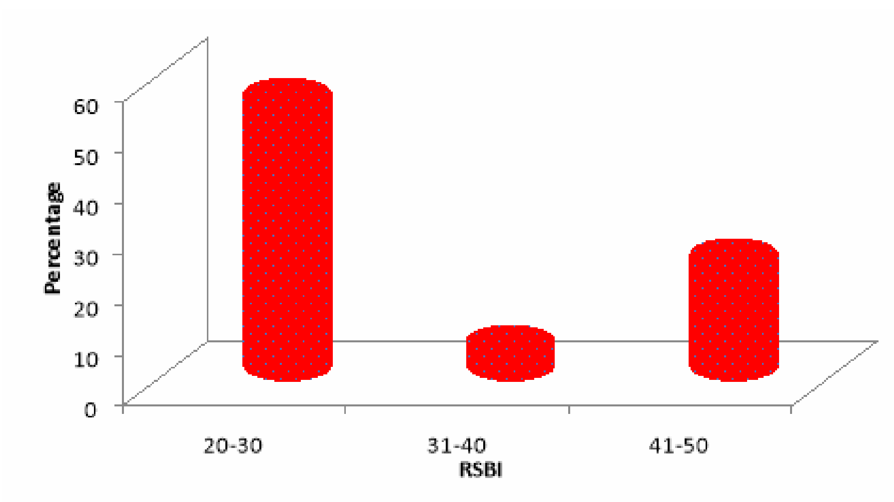


FIGURE 19: BAR GRAPH SHOWING THE RSBI OF THE PATIENTS STUDIED

TABLE 7: DIAGNOSIS

Diagnosis	No. of patients	%
Hypoglycemic encephalopathy	3	7.3
Organophosphorous poisioning	3	7.3
Acute exacerbation of COPD	2	4.9
CKD with MODS	2	4.9
Left MCA infarct with seizure disorder	2	4.9
Postpartum cardiomyopathy	2	4.9
SDH with midline Shift	2	4.9
Snake bite with neurotoxicity, haematotoxicity	2	4.9
Type II Respiratory Failure	2	4.9
Unknown compound consumption	2	4.9
Acute Coronary Syndrome	1	2.4
Amitriptylline poisoining	1	2.4
Aspiration Pneumonia	1	2.4
Bronchopenumonia	1	2.4
Cerebral Venous Thrombosis	1	2.4
Covid positive with bronchopneumonia	1	2.4
DAI with multiple facial bone fracture	1	2.4
Electric burns with pneumothorax	1	2.4
Isopropyl alcohol consumption	1	2.4
K/C/O status epileticus, autism	1	2.4
Left femur fracture with respiratory distress	1	2.4
Liver abscess with exacerbation of asthma	1	2.4
Mild Head Injury	1	2.4
Partial Hanging	1	2.4
Post-Operative case of cranioplasty	1	2.4
Right Hemiplegia with UML palsy	1	2.4
Right infarct with CVA	1	2.4
Septic Encephalopathy with neuroinfection	1	2.4
Severe ARDS with bronchopneumonia	1	2.4
Total	**41**	**100.0**

From the above table it was noticed that the patients selected for extubation had a variety of underlying pathological conditions and there was no bais in the selection of these patients.

TABLE 8: DIAPHRAGMATIC EXCURSION (DE) ASSESSMENT PRIOR TO PS AND PRIOR TO EXTUBATION OF PATIENTS STUDIED

OBSERVATION	Prior to PS	Prior to extubation	difference	t value	P value
1st	1.68±0.41	1.81±0.27	-0.127	-2.458	0.018*
2nd	1.61±0.31	1.84±0.30	-0.225	-0.663	0.511
3rd	1.61±0.35	1.85±0.27	-0.235	4.575	<0.001**
AVERAGE	1.63±0.33	1.83±0.26	-0.197	1.657	0.105

The above table showed that three values of Diaphragmatic excursion were taken prior to pressure support and also prior to extubation and amongst these three values it was found that the 3rd value of DE with 1.61±0.35 was strongly significant with a P value <0.001 and the next was the 1St value of DE taken as 1.68±0.41 and was considered moderately significant with a P value of 0.018. Most of the values obtained for DE was found to be above 1.5cm from the graph in prior to PS and also prior to extubation. DE being higher just prior to extubation.

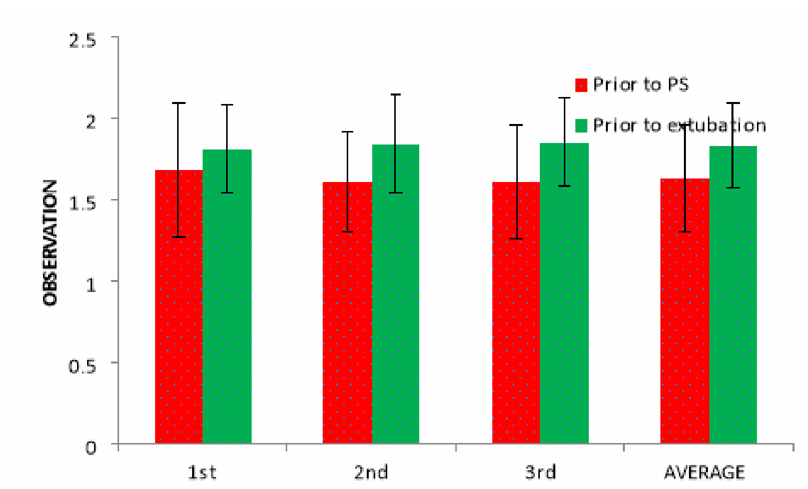


FIGURE 20: BAR GRAPH SHOWINGDIAPHRAGMATIC EXCURSION (DE) ASSESSMENT PRIOR TO PS AND PRIOR TO EXTUBATION OF PATIENTS STUDIED

TABLE 9: DIAPHRAGMATIC THICKENING FRACTION (dTF)- ASSESSMENT PRIOR TO PS AND PRIOR TO EXTUBATION OF PATIENTS STUDIED

OBSERVATION	Prior to PS	Prior to extubation	difference	t value	P value
1st	57.30±26.02	62.86±24.71	-5.561	-1.408	0.167
2nd	57.00±19.86	62.67±18.52	-5.676	-1.850	0.072+
3rd	55.52±21.96	66.22±17.14	-10.700	-3.742	0.001**
AVERAGE	54.96±17.94	63.87±17.70	-8.908	-3.718	0.001**

In the above table three values of Diaphragmatic thickening fraction was taken one before pressure support and one prior to extubation and an average value was taken. It was found that the 3rd value of dTF with 55.52±21.96 was found to be strongly significant alongwith the average value which was taken as 54.96±17.94 and both their P value was 0.001.

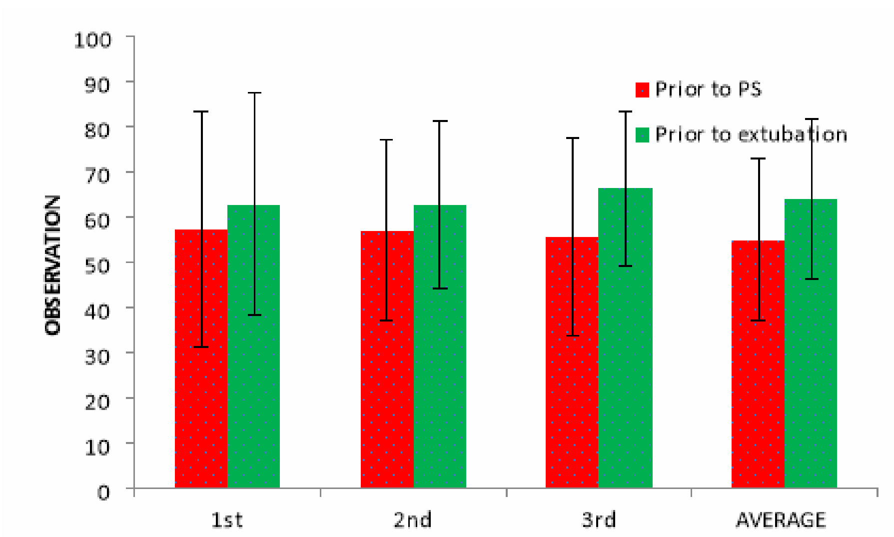
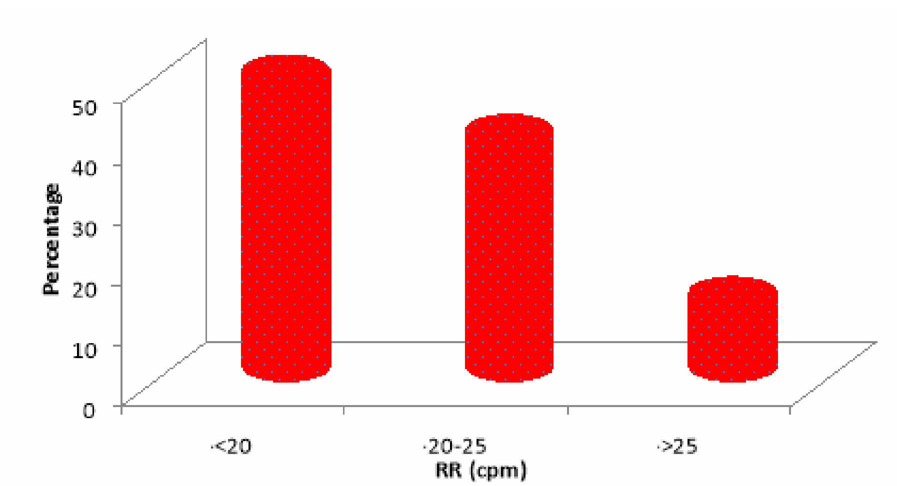


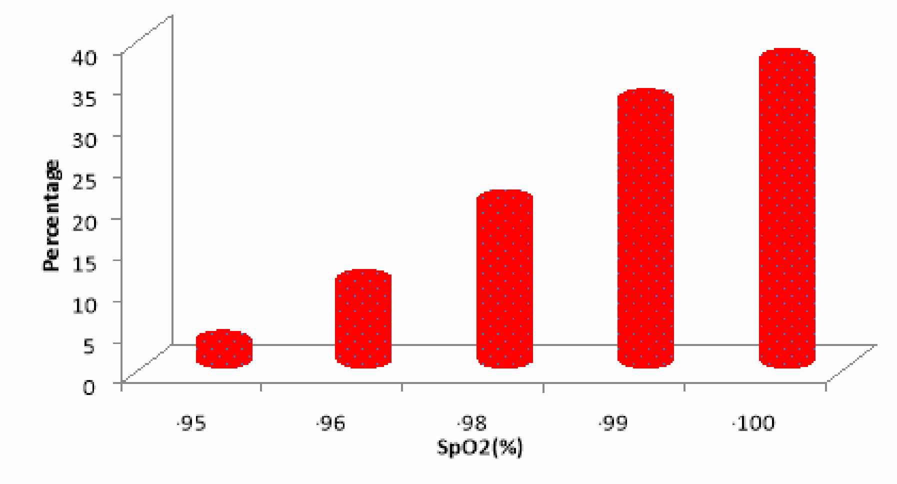
FIGURE 21: BAR GRAPH SHOWINGDIAPHRAGMATIC THICKENING FRACTION (dTF)- ASSESSMENT PRIOR TO PS AND PRIOR TO EXTUBATION OF PATIENTS STUDIED

TABLE 10: RESULTS OF THE STANDARD CRITERIA FOR EXTUBATION

Standard criteria for extubation	**No. of patients (n=41)**	**%**
RR (cpm)		
• <20	20	48.8
• 20-25	16	39.0
• >25	5	12.2
SpO2(%)		
• 95	1	2.4
• 96	4	9.8
• 98	8	19.5
• 99	13	31.7
• 100	15	36.6
MV (litre)		
• <7	7	17.1
• 7-10	25	61.0
• >10	9	22.0
TV (ml)		
• 400	3	7.3
• 420	3	7.3
• 450	3	7.3
• 460	2	4.9
• 480	7	17.1
• 500	23	56.1

The above table showed the different values of RR,TV,MV and spO2 of all the patients which were considered as the standard criteria for extubation. It was found that RR of 20 patients (48.8%) was below 20cpm. The Sp02 of 15 patients (36.6%) was found to be 100%. The Minute ventilation of 25 patients(61%) was between 7-10Litre. Tidal volume of 23 patients (56.1) was kept at 500ml.





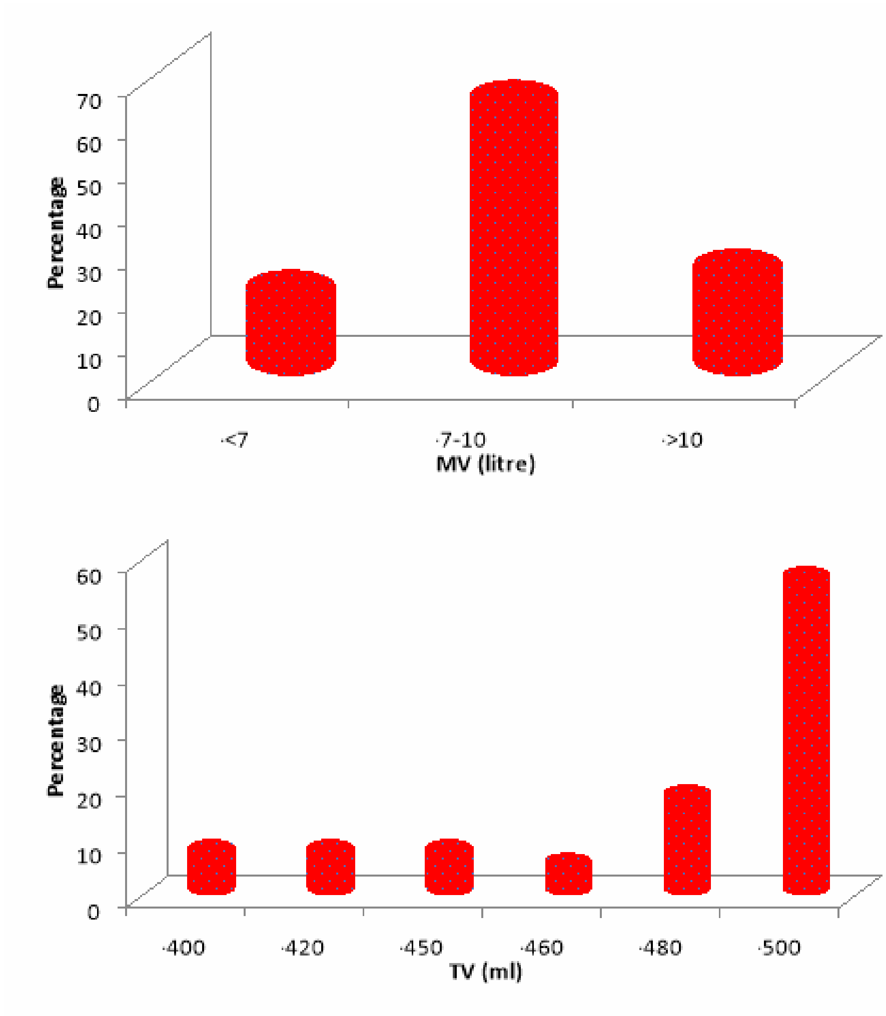


FIGURE 22: BAR GRAPH STANDARD CRITERIA FOR EXTUBATION

TABLE 11: THE MEAN VALUE OF STANDARD CRITERIA FOR EXTUBATION

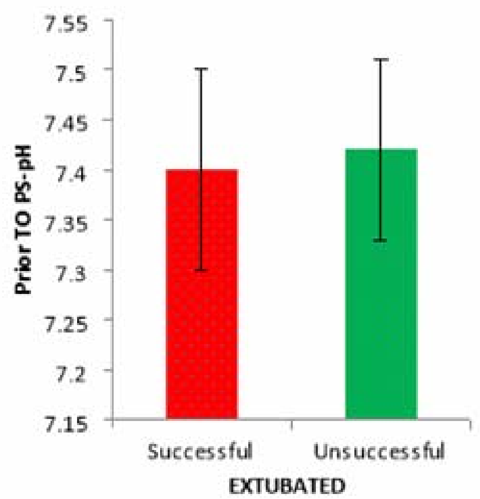
Standard criteria for extubation	Min	Max	Mean	SD
RR (cpm)	14.00	30.00	20.06	3.83
SpO2 (%)	96.00	100.00	98.83	1.27
MV (litre)	4.50	11.90	8.36	1.92
TV (ml)	400.00	500.00	479.71	28.85

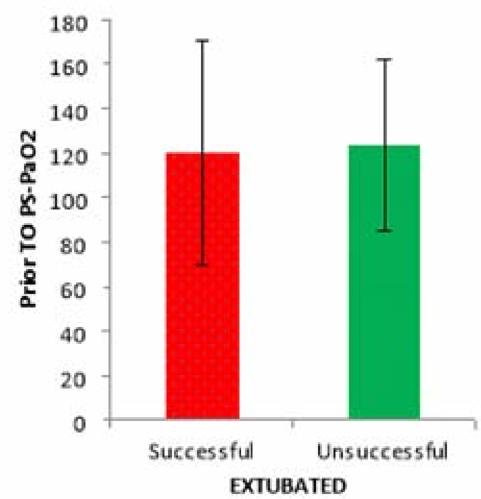
The above table showed the min,max, mean and the standard deviation value of the standard criteria for extubation. It was found that the RR value was 20±3.83, SpO2 was 98.83±1.27, MV was 8.36±1.92 and the TV was 479.71±28.85.

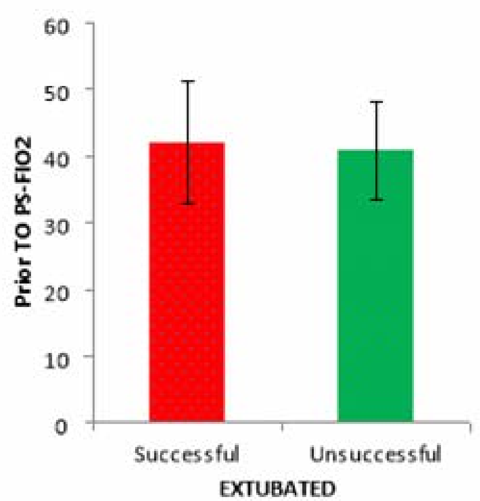
TABLE 12: COMPARISION OF STUDY VARIABLES ACCORDING TO SUCCESSFUL AND UNSUCCESSFUL EXTUBATION.

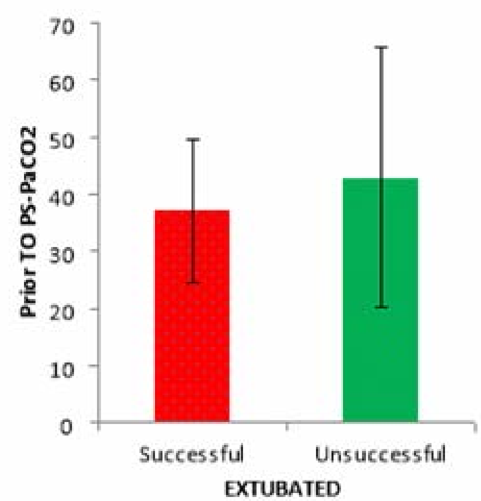
Variables	**EXTUBATED**		**Total**	**P value**
	Successful	**Unsuccessful**		
Prior TO PS				
• pH	7.40±0.10	7.42±0.09	7.40±0.10	0.635
• PaO2	120.26±50.53	123.67±38.55	120.76±48.55	0.876
• FIO2	42.00±9.17	40.83±7.36	41.83±8.86	0.770
• PaCO2	37.11±12.52	42.83±22.73	37.95±14.21	0.369
Prior to EXTUBATION				
• Ph	7.43±0.06	7.50±0.08	7.44±0.07	0.013*
• PaO2	123.37±56.85	143.50±72.19	126.32±58.74	0.445
• FIO2	35.57±2.02	35.00±0.00	35.49±1.87	0.497
• PaCO2	34.94±7.35	33.33±7.09	34.71±7.25	0.621
Standard criteria for EXTUBATION				
• RR (cpm)	20.06±3.83	21.50±4.97	20.27±3.98	0.418
• SpO2 (%)	98.83±1.27	98.50±1.87	98.78±1.35	0.589
• MV (litre)	8.36±1.92	10.08±2.11	8.61±2.02	0.052+
• TV (ml)	479.71±28.85	466.67±51.64	477.8±32.60	0.372

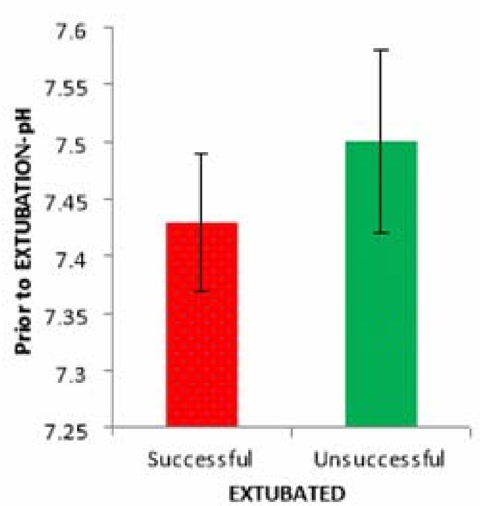
The above table compares the rate of successful and unsuccessful extubation based on the ABG value obtained prior to pressure support, prior to extubation and also the routine standard criteria taken for extubation.

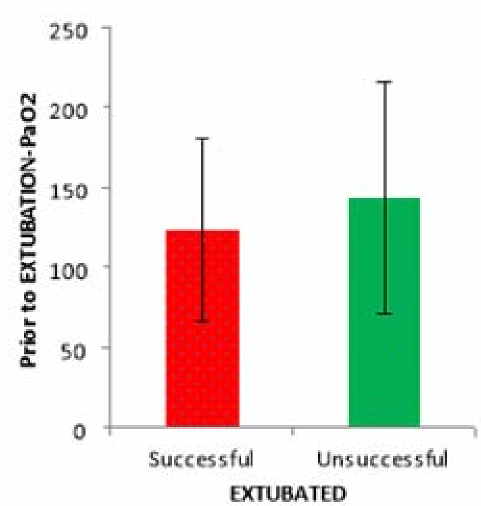

7.55
7.5
7.45
7.4
7.35
7.3
7.25
7.2
7.15
Prior TO PS-pH
Successful
Unsuccessful
EXTUBATED


180
160
140
120
100
80
60
40
20
0
Prior TO PS-PaO2
Successful
Unsuccessful
EXTUBATED


60
50
40
30
20
10
0
Prior TO PS-FIO2
Successful
Unsuccessful
EXTUBATED


70
60
50
40
30
20
10
0
Prior TO PS-PaCO2
Successful
Unsuccessful
EXTUBATED


7.6
7.55
7.5
7.45
7.4
7.35
7.3
7.25
Prior to EXTUBATION-pH
Successful
Unsuccessful
EXTUBATED


250
200
150
100
50
0
Prior to EXTUBATION-PaO2
Successful
Unsuccessful
EXTUBATED

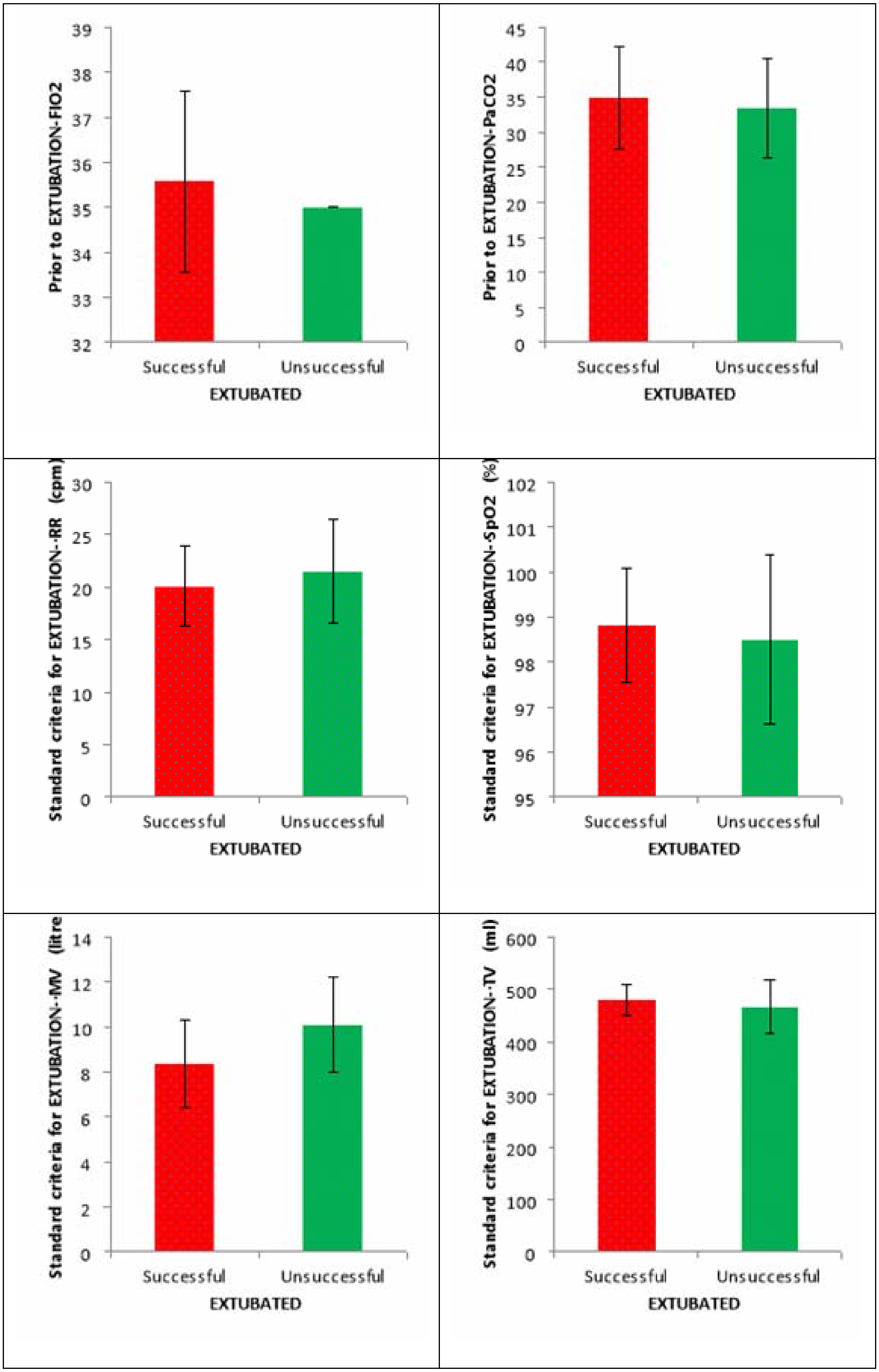

Prior to EXTUBATION-FIO2
39
38
37
36
35
34
33
32
Successful
Unsuccessful
EXTUBATED
Prior to EXTUBATION-PaCO2
45
40
35
30
25
20
15
10
5
0
Successful
Unsuccessful
EXTUBATED
Standard criteria for EXTUBATION--RR (cpm)
30
25
20
15
10
5
0
Successful
Unsuccessful
EXTUBATED
Standard criteria for EXTUBATION-SpO2 (%)
102
101
100
99
98
97
96
95
Successful
Unsuccessful
EXTUBATED
Standard criteria for EXTUBATION--MV (litre
14
12
10
8
6
4
2
0
Successful
Unsuccessful
EXTUBATED
Standard criteria for EXTUBATION--TV (ml)
600
500
400
300
200
100
0
Successful
Unsuccessful
EXTUBATED

FIGURE 23: BAR GRAPH SHOWING COMPARISION OF STUDY VARIABLES ACCORDING TO SUCCESSFUL AND UNSUCCESSFUL EXTUBATION.

Significant figures

+ Suggestive significance (P value: $0.05<P<0.10$)

* Moderately significant (P value:$0.01<P \leq 0.05$)

** Strongly significant (P value : $P\leq 0.01$)

DISCUSSION

Mechanical ventilation is considered to be as a life saving procedure in acute respiratory failure, trauma and in post-operative period. How-ever good, prolonged mechanical ventilation or early discontinuation both are considered to be equally bad. It is crucial as both these can cause increased mortality and morbidity in ICU.

Ventilation is linked to a number of serious problems, including nosocomial pneumonia, barotrauma, patient discomfort, airway difficulties, and respiratory muscle atrophy, and accounts for a considerable portion of the costs incurred by patients in critical care units..[51]

Similarly early discontinuation from mechanical ventilation can also lead to multiple problems. Patients may hyperventilate due to hypoxia, pain, anxiety or inappropriate ventilator settings. Early signs of weaning failure includes use of accessory muscles and paradoxical abdominal movements. Tachypnea, dyspnea, chest pain, asynchrony and diaphoresis.

Weaning from the mechanical ventilation is a challenging decision, it means complete transition from mechanical breathing support to patient's own respiratory drive support. This
transition is very critical and needs accurate, intense, confident decision based on trusted validated clinical, radiological and laboratory parameters to avoid the risk of weaning failure.[52]

Apart from the routine parameters used for extubation, nowdays ultrasonography of the diaphragm is used to predict the rate of successful extubation because the diaphragm is considered as the major respiratory muscle. Ultrasound is routinely used as a non-invasive bedside tool to assess diaphragmatic function and lung parenchyma status. It can assess percentage change in diaphragmatic thickness from expiration to inspiration (diaphragmatic thickening fraction, DTF) and amplitude of diaphragmatic dome movements in respiratory cycle (diaphragmatic excursion, DE) which are indicators of strength of diaphragmatic contractions. [53]

As ultrasonography of the diaphragm was not used routinely in our institute for the prediction of the weaning failure or success, we conducted this study to determine if the values obtained for dTF and DE can supplement the standard routine parameters used in ICU for extubation.

This was a prospective, double blind observational study conducted on 41 patients admitted in ICU requiring mechanical ventilation and satisfying the inclusion criteria at R. L. Jalappa Hospital and Research centre, Tamaka, Kolar in the period from January 2020 to May 2021. In the study, we divided doctors into the treating team and the research team. Treating team included the primary doctors working in ICU and evaluated the patient's readiness for pressure support ventilation. The research team did the diaphragm ultrasonography in those patients satisfying the inclusion criteria. The treating team was then blinded to dTF and DE results which was performed by the research team. Prior to extubation, all the patients had to satisfy the standard extubation criteria followed at RLJH, kolar.

Standard extubation criteria included 2 hours of pressure support ventilation with PEEP of 5 and pressure support of 8. It also includes respiratory rate <30, exhaled tidal volumes (>6ml/kg ideal body weight), RSBI (<105), and leak test (>100ml difference of tidal volumes).

The research team then scanned the diaphragm for dTF and DE twice before the extubation. First scan was done immediately prior to subjecting the patient to pressure support ventilation and the second scan was done prior to extubation. Total of three values were taken and then an average was taken of dTF and DE. According to our study, patients with dTF>35% and DE>1cm qualified for extubation. The USG measurments were done after the patients satisfied the standard extubation criteria.

Demographic Data:

The demographic parameter of our study consisted of Age, Sex and weight. It showed that majority of these patient belonged to the age group of 20-30(31.7%) The demographic profile in the study were comparable to similar other studies and these did not show any significant differences on statistical comparison.

After following the inclusion and the exclusion criteria the patients were then selected. It was found from various studies that most of the patients were above 18years of age. In our study we excluded obese patients(BMI>30kg/m2), females and those patients that had poor ultrasound images.

ABG Analysis:

In this study, two values of ABG were documented. One was taken prior to PS trial and one was taken just before extubation. Amongst all the values in ABG, only four were taken into consideration that was the pH, PaO2, PaCO2 and FiO2. It was found that pH with value of 7.40±0.10 and 7.44±0.07 prior to PS and Prior to extubation respectively was moderately significant and FiO2 with a value of 41.83±8.86 and 35.4 9±1.87 prior to PS and prior to extubation respectively was found to be strongly significant. PaO2 with value of 120.76±48.55 and PaCO2 with a value of 37.95±14.21 was not significant.

Standard variables considered for extubation:

The variables routinely taken into consideration was Respiratory Rate(RR), SpO2(%), Minute Ventilation (MV), Tidal Volume (TV) and Rapid Shallow Breathing Index (RSBI). From this study it was found that mean value of RR was 20.06±3.83 beats per minute, mean of SpO2 was 98.83±1.27 %, mean of MV was 8.36±1.92 Litre and mean of TV was 479.71±28.85 ml. The RSBI in majority of the patient (41.1%) were found to be between 20-30bpm/L.

A study conducted by **Zhou P et al** defined weaning failure as the requirement of mechanical ventilation protocols within 48hours after extubation.[54]

Diagnosis:

The patients selected for weaning were the ones who fit the criteria for extubation and had various underlying pathological conditions for mechanical ventilation that was corrected eventually. There was no bais found in the selection of these patients in our study.

Measurement of the dTF and DE

In our study we measured both these values in the semi-recumbent position with the head end elevated by 30 degree. We measured these values in the resting state. Most studies reported DE or DTF during the resting breath, while only two studies that were done by **Ferrari et al and Carie C et al** reported maximal DE or DTF during the forced breath.[36,55]

Ultrasounds measurements were conducted in the supine position in four other studies including **Kim et al** but another nine studies including the one by **Flevari et al** have performed the procedure in the semi-recumbent position.[56,57]

Value of Diaphragmatic Thickening Fraction (dTF)

In our study, three values of dTF was measured and then an average of these three values were taken, one recorded just prior to subjecting patients to PS ventilation and the second recording prior to extubation. Any patient having dTF>35% was considered for extubation. It was observed that dTF values more or less had values 54.96±17.94 % prior to PS and 63.87±17.70 prior to extubation. These values were taken from the average category with a P value<0.001 which was considered to be strongly significant.

Successfully Extubated- It was also found that 9 out of 41 patients who were successfully extubated had dTF<35%. 8 out of these 9 had dTF of 34% and only 1 had dTF of 28%.

Re-Intubation- It was seen that only 3 out of 41 patients were re-intubated and all these 3 had dTF>35%.

However in the study conducted by **Gottessman E** diaphragm Thickening fraction ranged from 22 to 78% with a mean Thickening fraction of 38.4%. Mean thickening fraction of the right hemidiaphragm was 35.4% while the mean Thickening fraction of the left hemidiaphragm was 41.4%.[23]

In our study, we measured only the right side of the diaphragm.

Value of Diaphragmatic Excursion

In our study, we obtained three values of DE prior to PS and prior to extubation and then an average value was taken similar to the way dTF was done. Any patient having DE>1cm was considered for extubation. It was seen that DE had an average value of 1.63±0.33cm prior to PS and 1.83±0.26cm prior to extubation. The 3rd value had DE of 1.61±0.35cm prior to PS and 1.85±0.27cm prior to extubation and hence was considered as strongly significant with P value<0.001.

Successfully Extubated- It was found that 9 out of 41 patients who were successfully extubated had DE>1cm despite having dTF<35%.

Re-Intubation- It was seen that out of the 3 patients who were re-intubated all of them have DE>1cm and dTF>35%

In the study conducted by **Youssriah Y et al** excursion in normal breathing ranged from 0.9 to 3.6 cm with a mean of 2 cm. Mean excursion for the right hemidiaphragm was 1.85 cm and mean excursion for the left hemidiaphragm was 2.31 cm [58]

However, the findings of related studies were inconsistent and lacked statistical power, and the clinical significances of DE and DTF still remained controversial. **Lerolle et al**demonstrated that DE correlated well with transdiaphragmatic pressure and suggested that DE could reflect diaphragmatic dysfunction.On the contrary, **Umbrello et al** believed that DTF rather than DE was a reliable index of respiratory effort and diaphragmatic contractile function.[59,60]

STRENGTHS

In our study we measured the diaphragmatic thickening fraction(dTF) and diaphragmatic excursion(DE) for all those patients who were planned for weaning from mechanical ventilation and who met the inclusion and the exclusion criteria. These measurements were taken on a trial basis subjecting the researchers to a blind study and were not included along with the standard protocol followed for extubation.

It was observed from our study that out of 41 patients on whom the study was done, 37 patients were successfully extubated, had more than the normal values considered for dTF and DE, however 9 out of these 37 patients despite having slightly lower value of dTF(34%) and only 1 out of the 9 had dTF of 28% were also extubated. Despite having dTF of 34%, all these 8 patients had more than 1cm value for DE. Hence the value of dTF of 34% in all these 8 patients could be neglected as it was at the borderline. The only patient who had a dTF of 28% could be due to poor ultrasound imaging.

We also observed that only 3 patients were re-intubated. However, out of these 3 patients that were re-intubated two of them had type II respiratory failure and only one patient was re-intubated due to airway compromise. One patient was extubated onto NIV, that was also later weaned off and patient was doing well.

Hence, dTF and DE can be used along with the routine parameters for regular extubation as bedside ultrasonography is not only easy and convenient but also a reliable parameter in predicting the outcome of weaning.

LIMITATIONS

This study can only be done in a tertiary care hospital with a dedicated critical care unit for trauma, surgical and medical patients. Our ICU had an infrastructure that ensured comprehensive care and provided bedside ultrasonography for the assessment of each patient who was suitable for our study.

Apart from the exclusion criteria, we could not carry out this study on obese individuals with a BMI>30kg/m2 and female patients especially the parturients. The assessment of dTF and DE was considered to be difficult in patients with repeated poor ultrasound image, non-cooperative patients and also highly restless patients. We also chose to evaluate only the right hemidiaphragm because the acoustic window provided by the liver made it easier to measure dTF and DE.

Hence to come to any conclusion regarding the ultrasonography of the diaphragm to predict successful extubation along with the standard criteria for extubation, we needed a larger group of study with a bigger sample size.

CONCLUSION

From our study we have concluded that bedside ultrasonography of the diaphragm always compliments the standard criteria for extubation and can be used for weaning the patients from mechanical ventilation as it is a point of care assessment, repeatable, reliable and is not associated with any complications. However, this study also had its limitations. The patients who were re-intubated had normal dTF and DE values whereas the 9 out of total patients who were successfully extubated in this study had a slightly lower dTF value and normal DE value. Along with the other limitations like obesity, pregnant females, measurement of the right diaphragm only and poor ultrasound images, a larger study group with a bigger sample size would be required to evaluate dTF and DE as parameters for successful extubation and to prevent re-intubation rates.

SUMMARY

This was a prospective, double blind observational study conducted on 41 patients admitted in ICU requiring mechanical ventilation and who satisfied the inclusion and exclusion criteria at R. L. Jalappa Hospital and Research centre, Tamaka, Kolar during the period from January 2020 to May 2021.

In this study, we divided doctors into the treating team and the research team. Treating team included the primary doctors working in ICU and evaluated the patient's readiness for pressure support ventilation. The research team did the diaphragm ultrasonography in those patients satisfying the inclusion criteria. The treating team was then blinded to dTF and DE results research team. Prior to extubation, all the patients had to satisfy the standard extubation criteria followed at our hospital.

The research team then scanned the diaphragm for dTF and DE twice before extubation. First scan was done immediately prior to subjecting the patient to pressure support ventilation and the second scan was done prior to extubation. Total of three values were taken and then an average was taken of dTF and DE. Any patient having dTF>35% and DE>1cm was considered for extubation after they satisfied the standard routine criteria used in ICU.

From the values of dTF and DE obtained we observed that out of 41 patients, 3 were re-intubated, 1 was extubated onto NIV and the remaining were successfully extubated.

Successful extubation-9 out of the 37 patients who were successfully extubated had lower value of dTF but all had more than 1cm for DE. Out of these 9 patients, 8 of them had dTF of 34% which can be neglected and only 1 patient out of these 9 had dTF of 28%, the probable cause of this being poor ultrasound imaging. It was concluded that one patient inspite of having lower value of dTF(28%) and DE value of 1.74 was successfully extubated.

Re-intubation- 3 out of 41 patients were re-intubated and only 1 was extubated onto NIV. All these patients had dTF>35% and DE>1cm. The 2 patients out of 3 were re-intubated due to Type II respiratory failure as these were COPD patients. The reasons being thick secretions, post-extubation laryngeal edema or various other triggering factor for exacerbation. Only 1 (7.31%) patient out of these 3 was re-intubated in view of airway compromise because the patient was a known case of seizure disorder.

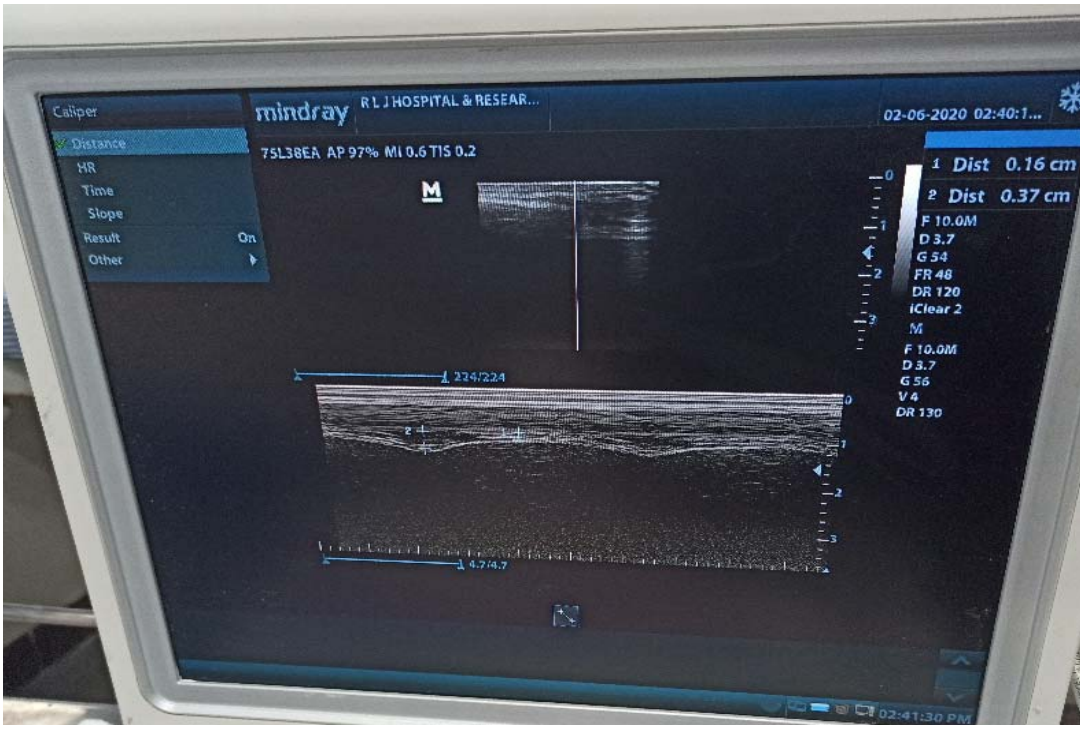
NIV- Only 1 patient out of the 41 was extubated onto NIV and then weaned off from NIV. This patient had a dTF of 46% and DE of 1.59cm hence was extubated onto NIV due to PaO2 being less than 80 and SpO2 was not more than 92%

Re-admissions- There were no re-admissions in this study of 41 patients.

Hence from our study we have concluded that bedside ultrasonography of the diaphragm can compliment the standard criteria for extubation and can be done for weaning of patients from mechanical ventilation as it is a point of care assessment, repeatable, reliable and is not associated with any complications. However, this study also had its limitations. This study could be done only in hospitals that had an ICU with bedside USG for assessment. It could not be done on both the sides of the diaphragm, obese indivduals and also in pregnant females. Hence a large study with a bigger sample size would be required to evaluate dTF and DE as parameters for successful extubation and to prevent re-intubation rates.

ULTRASONOGRAPHY PICTURES

DIAPHRAGMATIC THICKENING FRACTION



DIAPHRAGMATIC EXCURSION

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ANNEXURES

ANNEXURE-I

PROFORMA

PERSONAL DETAILS:

NAME: AGE: SEX:

ADDRESS: DATE OF STUDY:

OCCUPATION:

HEIGHT: IBW:

TELEPHONE NO: UHID NO:

OBSERVATIONS:

1) Duration of mechanical ventilation

2)ABG:

DATE:	PRIOR TO PS	PRIOR TO EXTUBATION
TIME:		
pH		
PaO2/FiO2		
PaCo2		
Hb		

CLINICAL FINDINGS:

1) Respiratory Rate:

2)Spo2:

3) Minute ventilation:

4)Tidal Volume:

5) RSBI:

6) Mean Arterial Pressure:

7) Heart Rate:

CO-MORBIDITIES:

CLINICAL DIAGNOSIS:

REASON FOR MECHANICAL VENTILATION:

ACUTE PROBLEMS: (Prior to pressure support)

OBSERVATIONS:

Prior to PS	**1st READING**	**2ND READING**	**3RD READING**	**AVERAGE**
DE(mm)				
dTF(%)				

Prior to Extubation	**1st READING**	**2ND READING**	**3RD READING**	**AVERAGE**
DE(mm)				
dTF(%)				

DE= movements of diaphragm during inspiration-movements of diaphragm during expiration.

dTF= (inspiratory thickness of diaphragm-expiratory thickness of diaphragm)/expiratory thickness of diaphragm*100

ANNEXURE-II

PATIENT INFORMATION SHEET

TITLE: ULTRASONOGRAPHY OF THE DIAPHRAGM TO PREDICT SUCCESSFUL EXTUBATION.

I, **DR.ISHITA RAJ** Post graduate in the department of Anaesthesiology, Sri Devaraj Urs Medical College,Kolar. We are carrying out above mentioned study at RLJH, Tamaka, Kolar. The study has been reviewed and approved by the institutional ethical review board. We will be measuring dTF and DE using ultrasonography in patients who are on mechanical ventilation and are appropriate for weaning onto pressure-support ventilation. This will be done in addition to the standard extubation criteria and will not be considered as a basis for extubation.

Measurement of dTF and DE will merely help in estimating the number of patients that can be prevented from re-intubation.

Participation in this study doesn't involve any added cost to the patient. There is no compulsion to participate in this study and you will not be affected with regard to patient care, if you wish not to be part of this study.

All the information collected from the patient will be kept confidential and will not be disclosed to any outsider, unless compelled by the law. The information collected will be used only for this study. I request your kind self to give consent for the above mentioned research project.

For any further clarification you are free to contact,

Dr. ISHITA RAJ
(Post Graduate in Anaesthesiology)
Mobile no:9686756186.

Dr. SURESH KUMAR.N.
(Professor in Anaesthesiology)
Mobile no:9008222550

ANNEXURE-III

INFORMED CONSENT FORM

Name of the institution: Sri Devaraj Urs Academy of Higher education and research

I, Mr/Mrs, , of the patient have been explained that the patient will be included in the study, ULTRASONOGRAPHY OF DIAPHRAGM TO PREDICT SUCCESSFUL EXTUBATION.

I have been explained about the procedure, monitoring, clinical findings and investigations performed in a language best understood by me and the same will be documented for the study purpose. I have been explained that my participation in this study is entirely voluntary and I can withdraw from the study anytime and this will not affect the treatment for the patient's ailment.

I have understood that all the patient's details recorded during the study are kept confidential while publishing or sharing the findings.

I, in my sound mind on behalf of the patient give consent to be part of this study.

Signature

Name:

Signature of the witness1:

Name:

Signature of the witness2:

Name:

Date:

Place:

Signature of the doctor:

For any further clarification you are free to contact,

Dr. ISHITA RAJ

(Post Graduate in Anaesthesiology)

Mobile no:9686756186.

Dr. SURESH KUMAR.N.

(Professor in Anaesthesiology)

Mobile no:9008222550

KEY TO MASTER CHART

Sl.No	Serial Number
UHID No.	Unique Health Identification Number
M	Male
F	Female
Kgs	Kilogram
ABG	Arterial Blood Gas
PS	Pressure Support
pH	Potential of Hydrogen
mmHg	Millimeter of Mercury
PaO2 (mmHg)	Partial Pressure of Oxygen
FiO2 (%)	Fractional Inspired Oxygen
PaCo2 (mmHg)	Partial Pressure of Carbon Dioxide
RR	Respiratory Rate
cpm	Cycles per Minute
Mm	Millimeter
L	Litre
mL	Millilitre
SpO2 (%)	Oxygen Saturation
MV(l)	Minute Ventilation
TV(ml)	Tidal Volume
RSBI(cpm/L)	Rapid Shallow Breathing Index
cm	Centimeter

MASTER CHART

SL.NO	UHID NO	AGE (YEAR)	GENDER	WEIGHT(KG)	ABG						STANDARD CRITERIA FOR EXTUBATION					DIAGNOSIS	OBSERVATION										CONCLUSION
					PRIOR TO PS			PRIOR TO EXTUBATION									TO PRESSU				AVER/	TO EXTUB					
					pH	PaO2/FiO2	PaCO2	pH	PaO2/FiO2	PaCO2	RR(cpm)	SpO2(%)	MV(litre)	TV(ml)	RSBI(cpm/L)		dTF(%) /DE(cm)	1st	2nd	3rd		DE(cm)/d	1st	2nd	3rd	AVERAGE	
1	844817	45 years	Male	77	7.44	70/35	37	7.47	81/35	34	22	99	11	500	10/0.5=20	Left femur fracture with respiratory distress	DE(cm)	2.53	1.97	2.21	2.23	DE(cm)	1.55	1.47	1.53	1.51	Successfully extubated
																	dTF(%)	76.4	68.5	36.1	60.3	dTF(%)	39.1	54.3	48.3	47.2	
2	844981	65years	Male	70	7.5	120/50	29	7.46	109/35	36	25	98	12	400	12/0.4=30	Hypoglycemic encephalopathy	DE(cm)	1.56	1.24	1.38	1.39	DE(cm)	1.87	1.56	1.34	1.59	Successfully extubated
																	dTF(%)	56	75	68	66.3	dTF(%)	36.3	35.2	42.8	38.1	
3	847601	23 years	Female	46	7.54	69/40	34	7.54	52/40	34	30	98	5	420	12/0.42=28	Partial Hanging	DE(cm)	1.22	1.71	1.38	1.43	DE(cm)	1.51	1.62	2.26	1.79	Successfully extubated
																	dTF(%)	46	53	40	46.3	dTF(%)	56	64	62	60.7	
4	847838	30 years	Female	54	7.45	117/40	24	7.42	135/35	27	29	98	7	400	14/0.4=35	K/C/O status epileticus, autism	DE(cm)	1.14	1.14	1.14	1.14	DE(cm)	1.56	1.62	1.6	1.59	Reintubated
																	dTF(%)	33	40	30	34	dTF(%)	42	45	52	46.3	
5	848186	26 years	Female	45	7.25	96/35	83	7.6	82/35	30	24	100	13	500	12/0.5=24	Organophosphorous poisioning	DE(cm)	1.44	1.55	1.22	1.4	DE(cm)	1.86	1.82	1.76	1.81	Reintubated within one hour
																	dTF(%)	45	42	54	47	dTF(%)	52	54	62	56	
6	849543	55 years	Female	47	7.46	81/35	44	7.51	91/35	41	22	96	9	480	14/0.48=29	Acute exacerbation of COPD	DE(cm)	1.71	1.79	1.71	1.73	DE(cm)	2.21	2.16	2.13	2.16	Successfully extubated
																	dTF(%)	34	30	21	28	dTF(%)	42	54	51	49	
7	849755	80 years	Male	76	7.34	58/70	33	7.33	153/35	30	26	100	9	480	16/0.4=40	Acute exacerbation of COPD	DE(cm)	1.87	1.63	1.79	1.74	DE(cm)	1.96	2.12	2.01	2.03	Successfully extubated
																	dTF(%)	75	51	57	61	dTF(%)	76	64	72	70.7	
8	849587	75 years	Male	78	7.36	75/35	31	7.47	95/35	40	22	98	11	480	12/0.4=30	Right infarct with CVA	DE(cm)	2.04	2.04	2.12	2.06	DE(cm)	2.16	2.08	2.12	2.12	Successfully extubated
																	dTF(%)	120	131	72	107	dTF(%)	86	76	83	81.6	
9	849509	51 years	Female	52	7.41	86/35	40	7.44	98/35	37	18	99	7	460	14/0.46=30	Aspiration Pneumonia	DE(cm)	1.27	1.63	1.44	1.44	DE(cm)	1.32	1.64	1.76	1.57	Successfully extubated
																	dTF(%)	37	67	32	45	dTF(%)	46	54	61	53.6	but arrested 2 days later
10	846186	65 years	Male	74	7.31	81/45	36	7.35	86/35	33	16	99	11	500	12/0.5=24	Acute Coronary Syndrome	DE(cm)	1.56	1.43	1.76	1.58	DE(cm)	1.86	1.93	2.06	1.95	Successfully extubated
																	dTF(%)	125	72	68	84	dTF(%)	86	74	71	77	
11	850591	70 years	Male	72	7.2	84/35	46	7.26	187/35	47	16	98	11	500	20/0.5=40	Snake bite with neurotoxicity, haematotoxicity	DE(cm)	1.97	1.7	1.43	1.7	DE(cm)	2.6	3.13	2.75	2.82	Successfully extubated
																	dTF(%)	62	73	64	66	dTF(%)	133	143	138	138	
12	850999	50 years	Male	72	7.5	72/35	38	7.43	81/35	41	18	99	9	500	18/0.5=36	Electric burns with pneumothorax	DE(cm)	2.28	2.05	2.05	2.12	DE(cm)	2.16	2.08	2.1	2.11	Successfully extubated
																	dTF(%)	33	35	37	34	dTF(%)	45	54	51	50	
13	874254	25 years	Male	65	7.39	159/60	36	7.42	135/35	27	16	96	5.6	450	16/0.45=35	Snake bite with neurotoxicity, haematotoxicity	DE(cm)	1.14	1.14	1.14	1.14	DE(cm)	2.06	2.12	2.04	2.07	Successfully extubated
																	dTF(%)	33	40	30	34	dTF(%)	42	54	56	50.6	
14	875669	76 years	Male	61	7.43	152/50	50	7.41	128/35	51	14	100	9	500	18/0.5=36	Liver abscess with exacerbation of asthma	DE(cm)	2.28	2.05	2.05	2.12	DE(cm)	2.06	2.14	2.08	2.09	Successfully extubated
																	dTF(%)	33	35	33	34	dTF(%)	46	52	50	49.3	
15	875931	52 years	Female	52	7.51	163/35	37	7.6	239/35	32	16	99	11	500	20/0.5=40	Left MCA infarct with seizure disorder	DE(cm)	1.97	1.7	1.43	1.7	DE(cm)	2.06	1.98	2.04	2.02	Reintubated
																	dTF(%)	62	73	64	66	dTF(%)	64	72	60	65	
16	878098	65 Years	Female	52	7.43	110/35	36	7.44	125/35	33	26	100	9	480	22/0.48=45	DAI with multiple facial bone fracture	DE(cm)	1.87	1.63	1.79	1.74	DE(cm)	2.02	1.96	2.04	2	Successfully extubated
																	dTF(%)	75	51	57	61	dTF(%)	82	56	74	70.6	
17	879738	68 years	Male	54	7.4	225/50	31	7.44	158/35	32	18	99	8.6	500	14/0.5=28	CKD with MODS	DE(cm)	1.23	1.19	1.26	1.22	DE(cm)	1.86	1.74	1.68	1.76	Successfully extubated
																	dTF(%)	79	95	93	89	dTF(%)	76	84	86	82	
18	880276	70 years	Male	74	7.04	90/50	72	7.38	70/35	34	16	99	4.6	500	12/0.5=24	Bronchopenumonia	DE(cm)	1.47	1.34	1.36	1.39	DE(cm)	1.62	1.64	1.76	1.67	Successfully extubated
																	dTF(%)	63	60	96	61.3	dTF(%)	72	64	76	70.6	
19	879253	20 Years	Female	62	7.55	209/35	27	7.47	274/35	36	22	99	8.7	450	16/0.45=35	Postpartum cardiomyopathy	DE(cm)	1.35	1.28	1.32	1.31	DE(cm)	1.62	1.86	1.74	1.74	Successfully extubated
																	dTF(%)	40	58	40	40	dTF(%)	52	56	64	57.3	
20	710708	56 Years	Male	62	7.3	62/35	35	7.44	88/35	22	26	100	7.8	500	16/0.5=32	CKD with MODS	DE(cm)	1.34	1.6	1.56	1.5	DE(cm)	1.76	1.84	2.06	1.88	Successfully extubated
																	dTF(%)	81	72	55	69.3	dTF(%)	82	64	76	74	
21	882542	24 Years	Male	76	7.38	237/35	34	7.45	97/35	32	16	100	8.6	500	16/0.5=32	Organophosphorous poisioning	DE(cm)	2.28	2.05	2.05	2.12	DE(cm)	2.06	2.14	2.08	2.09	Successfully extubated
																	dTF(%)	33	35	37	34	dTF(%)	42	46	43	43.6	
22	883075	26 Years	Male	72	7.38	137/35	26	7.47	83/35	35	20	100	7.8	500	12/0.5=24	Amitriptylline poisoining	DE(cm)	1.63	1.55	1.43	1.53	DE(cm)	1.76	1.84	1.81	1.8	Successfully extubated

MASTER CHART

																	dTF(%)	136	75	125	74	dTF(%)	76	82	84	80.6	
23	882566	28 Years	Male	78	7.45	159/40	29	7.38	275/40	32	18	100	5.8	500	14/0.5=28	Right Hemiplegia with UML palsy	DE(cm)	1.97	1.63	1.53	1.71	DE(cm)	1.86	1.76	1.94	1.85	Successfully extubated
																	dtF(%)	80	73	85	79.3	dTF(%)	82	81	79	80.6	
24	887616	57 Years	Male	56	7.4	181/35	22	7.31	125/35	21	24	98	6.1	500	24/0.5=48	Hypoglycemic encephalopathy	DE(cm)	2.04	2.36	2.28	2.22	DE(cm)	2.16	2.14	2.08	2.12	Successfully extubated
																	dTF(%)	82	50	85	72.33	dTF(%)	86	79	98	87.6	
25	889165	20 Years	Female	52	7.39	176/50	31	7.45	156/35	26	22	100	8.6	480	22/0.48=45	Organophosphorous poisioning	DE(cm)	1.76	1.83	1.69	1.76	DE(cm)	1.82	1.94	1.96	1.9	Successfully extubated
																	dTF(%)	75	81	81	79	dTF(%)	76	94	81	83.6	
26	889162	75 Years	Male	72	7.35	71/35	48	7.42	67/35	36	22	99	9.8	500	22/0.5=44	Left MCA infarct with seizure disorder	DE(cm)	1.22	1.14	1.38	1.24	DE(cm)	1.36	1.42	1.51	1.43	Successfully extubated
																	dTF(%)	37	34	56	42.3	dTF(%)	46	54	56	52	
27	889689	55 Years	Female	52	7.37	97/40	37	7.44	163/35	37	21	100	4.5	480	20/0.48=41.6	Type II Respiratory Failure	de(cm)	1.95	1.71	1.47	1.71	DE(cm)	1.87	1.91	1.96	1.91	Successfully extubated
																	dTF(%)	50	46	50	48.67	dTF(%)	61	67	64	64	
28	890226	79 Years	Male	68	7.31	97/35	34	7.36	97/35	32	18	98	8.6	500	14/0.5=28	Type II Respiratory Failure	de(cm)	1.25	1.17	1.52	1.31	DE(cm)	1.46	1.54	1.76	1.58	Successfully extubated
																	dTF(%)	44	34	25	34	dTF(%)	56	62	56	58	
29	894343	55 Years	Male	58	7.41	204/60	33	7.42	163/35	32	16	100	7.8	500	14/0.5=28	Mild Head Injury	de(cm)	1.86	1.86	2.25	1.99	DE(cm)	1.74	1.82	1.76	1.77	Successfully extubated
																	dTF(%)	37	67	32	45	dTF(%)	46	51	48	48.3	
30	894342	45 Years	Female	52	7.44	106/50	34	7.48	101/35	31	16	98	7.6	420	12/0.42=28	Unknown compound consumption	de(cm)	1.06	1.22	1.15	1.14	DE(cm)	1.56	1.61	1.32	1.49	Successfully extubated
																	dTF(%)	53	61	56	56	dTF(%)	56	64	64	61.3	
31	896196	25 Years	Male	67	7.46	109/35	33	7.43	73/35	36	18	96	7.8	460	14/0.46=30.4	Isopropyl alcohol consumption	DE(cm)	1.86	1.74	2.05	1.88	DE(cm)	1.92	1.74	1.75	1.8	Successfully extubated
																	dTF(%)	53	52	71	58	dTF(%)	56	51	64	57	
32	895515	66 Years	Male	68	7.44	148/50	34	7.5	204/35	34	22	99	11	500	10/0.5=20	SDH with midline Shift	DE(cm)	2.53	1.97	2.21	2.23	DE(cm)	1.96	1.82	1.84	1.87	Reintubated after 5 days
																	dTF(%)	39	54.3	48.3	47.2	dTF(%)	46	56	74	58.6	
33	897317	25 Years	Female	54	7.41	153/35	20	7.49	73/35	30	16	96	5.6	450	16/0.45=35.5	Postpartum cardiomyopathy	DE(cm)	1.14	1.14	1.15	1.14	DE(cm)	1.64	1.81	1.76	1.73	Successfully extubated
																	dTF(%)	33	40	30	34	dTF(%)	42	51	56	49.6	
34	895125	45 Years	Female	52	7.47	154/35	24	7.45	154/35	30	16	100	8.6	500	16/0.5=32	Cerebral Venous Thrombosis	DE(cm)	2.28	2.05	2.05	2.12	DE(cm)	1.86	1.92	1.76	1.84	Tracheostomised
																	dTF(%)	33	35	37	34	dTF(%)	54	61	56	57	
35	904100	45 Years	Male	64	7.45	149/50	33	7.52	123/35	28	22	100	8.6	500	22/0.5=44	Unknown compound consumption	DE(cm)	1.81	1.66	1.74	1.73	DE(cm)	1.92	1.86	1.74	1.84	Successfully extubated
																	dTF(%)	55	72	65	64	dTF(%)	62	64	76	67.3	
36	710846	27 Years	Male	67	7.46	96/35	36	7.35	98/35	47	18	100	9.4	500	18/0.5=36	Post Operative case of cranioplasty	de(cm)	1.21	1.42	1.32	1.31	DE(cm)	1.36	1.43	1.4	1.39	Successfully extubated
																	dTF(%)	36	47	55	47	dTF(%)	42	51	56	49.6	
37	902324	40 Years	Male	72	7.27	109/35	81	7.51	247/35	49	22	100	8.6	480	22/0.48=45	Septic Encephalopathy with neuroinfection	DE(cm)	1.78	1.72	1.51	1.67	DE(cm)	1.82	1.78	1.94	1.84	Successfully extubated
																	dTF(%)	83	69	61	71	dTF(%)	82	76	74	77.3	
38	897267	45 Years	Male	68	7.54	168/40	23	7.47	184/35	35	18	99	8.6	500	16/0.5=32	SDH with midline Shift	DE(cm)	1.64	1.56	1.61	1.6	DE(cm)	1.64	1.51	1.74	1.63	Successfully extubated
																	dTF(%)	42	51	56	49.6	dTF(%)	56	72	71	66.3	
39	896022	42 Years	Male	68	7.46	96/50	32	7.34	132/45	26	18	99	11	500	16/0.5=32	Hypoglycemic encephalopathy	DE(cm)	1.26	1.34	1.42	1.34	DE(cm)	1.34	1.46	1.52	1.44	Successfully extubated
																	dTF(%)	52	40	71	54	dTF(%)	158	26	66	83	
40	914282	29 Years	Male	72	7.39	61/45	58	7.43	50/35	50	24	99	9.4	420	18/0.42=42	Covid positive with bronchopneumonia	de(cm)	1.54	1.62	1.36	1.5	DE(cm)	1.61	1.72	1.63	1.65	Successfully extubated
																	dTF(%)	42	45	51	46	dTF(%)	46	52	51	49.6	
41	915653	35 Years	Male	71	7.39	64/50	55	7.45	47/35	47	22	95	9.8	400	18/0.4=45	Severe ARDS with bronchopneumonia	DE(cm)	1.62	1.56	1.34	1.5	DE(cm)	1.72	1.64	1.58	1.64	Extubated onto NIV
																	dTF(%)	46	54	52	50.6	dTF(%)	51	56	62	56.3	