Universitat de Girona

WEANING AND EXTUBATION IN THE ICU: A BIBLIOGRAPHIC REVIEW

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ABSTRACT

Background: The purpose of this project is to conduct a bibliography review of the extubating process and a respiration process called weaning, which are related to IMV. Weaning is a gradual process in which IMV begins to be withdrawn to initiate spontaneous breathing and ends in extubating the patient, who is admitted to the intensive care unit (ICU). Although the concept of this phase is well known, there is a wide variety of information about when is the right time to extubate the patient. Therefore, this work is broken down into different points. Firstly, general information is written about the respiratory system, how the patient is admitted into the ICU and the mechanical ventilation. Then we focus on the last phase of mechanical ventilation that allows IMV to come to an end and extubate the patient.

Aim: The main objective of the project was to identify the parameters of the right time to extubate a patient. To understand the weaning process in depth the following objectives were made. Identify the weaning process, the criteria to start the weaning and the criteria to identify weaning tolerance. And most importantly, to identify how the process is related to extubating, as well as the significance of weaning and extubating in the IMV process.

Methodology: To do this bibliographic review, a search algorithm was created for each database, from which the articles are extracted to write the results. The algorithms are made considering the inclusive and exclusive criteria, so the found articles are closer to the defined objectives we want to encounter.

Results: Eight articles were found that met the objectives. The articles outcomes point out that even though a clinician's view is really important in the process of weaning and the ending of IMV, it is recommended to make a decision following a standardized protocol and the criteria of an interdisciplinary team. Following a protocol is encouraged, but more research has to be done to be able to create a standard protocol.

Keywords: Ventilator weaning, airway extubation, invasive mechanical ventilation, intensive care unit, patient selection.

RESUM

Antecedents: L'objectiu d'aquest projecte és dur a terme una revisió bibliogràfica d'un procés d'extubació i del terme weaning, que consisteix en el procés de retirada gradual del suport del ventilador que s'ha de realitzar en un període clau (Timing) en que sigui possible la respiració fisiològica automàtica del pacient. Tot i que el concepte és ben conegut, existeix una gran quantitat d'informació sobre quan és el moment adequat per iniciar aquest procés i extubar el pacient. Per això el treball es desglossa en diferents punts. En primer lloc, s'escriu informació general sobre l'aparell respiratori, com ingressa el pacient a la UCI i la ventilació mecànica. A continuació, ens centrem en l'última fase de ventilació mecànica que permet que VMI arribi al seu final.

Objectiu: L'objectiu principal és identificar els paràmetres que s'han de complir per iniciar la extubació. Per tant relacionat amb aquest objectiu s'ha volgut identificar el procés de weaning, quins criteris el pacient ha de complir per identificar una bona tolerància a aquest, com es relacionen, així com la seva importància en el procés VMI. També conèixer quin és el moment adequat per iniciar el weaning i la extubació al pacient, identificant les característiques que ha de tenir el pacient d'UCI.

Metodologia: Les bases de dades de cerca utilitzades són Science Direct, PubMed i Scielo. El procediment inicial de la revisió bibliogràfica consisteix en crear un algorisme de cerca per a cada base de dades. El resultat correspon als articles alineats a l'objectiu d'estudi. Els algorismes s'apliquen d'acord les paraules clau, els criteris d'inclusió i exclusió, i els termes MESH estable

Resultats: S'han seleccionat vuit articles que donen resultat als objectius. Els resultats dels articles apunten a que, tot i que la visió del metge és realment important en el procés de Weaning i la finalització de VMI, es recomana prendre una decisió seguint un protocol estandarditzat i l'acord considerant el criteri de l'equip interdisciplinari. Tot i que es fomenta seguir un protocol, cal progressar la investigació per poder crear un protocol estàndard.

Paraules clau: Ventilator weaning, airway extubation, invasive mechanical ventilation, intensive care unit.

1. INTRODUCTION

The process of intubating a person and starting invasive mechanical ventilation is one of the most used techniques that someone can visibly perceive in the intensive care unit, ICU. This process is implemented in patients who have their lung function compromised and need a machine to support and substitute their breathing process (1).

Substituting a vital process such as the breathing process, requires continuous monitoring to be kept on the patient. To do so, people who are intubated get admitted into the intensive care unit, where continuous monitoring is possible (1).

During mechanical ventilation, a patient goes through different stages to reach the objective of recovery. One of the important stages is the weaning process. Weaning is started when it is wanted to gradually extubate a patient. Even though it is a process to end mechanical ventilation, it lasts almost half of the time that the patient spends with mechanical ventilation, which is approximately 40% (2).

Because the weaning process is almost the majority of the time that the patient spends with IMV, and because it is also known that prolonged IMV is related to complications, it is best to delay the weaning and extubation process (3). To do so, it is needed to know the criteria for a patient to be ready for extubation.

In my clinical rotation in the ICU, I was able to see how the decision to extubate the patient was not followed by a standardised protocol. Instead, it was a decision made with the clinician’s view. Of course, as I was curious about this process the idea for this project was created. In this project, I want to identify what are the criteria for extubating, as a simple search was not enough to identify these criteria because of the different variability of opinions. It is because of this that I made a bibliographic review about this topic.

2. CONCEPTUAL FRAMEWORK

2.1. RESPIRATORY SYSTEM

The respiratory system consists of organs and structures that enable lung ventilation and the exchange of gas (4). This system brings oxygen into the lungs to exchange it with carbon dioxide. Then it removes the carbon dioxide and passes oxygen into our bloodstream. Breathing happens when there is a pressure difference between the inside of the lungs and the atmospheric pressure (5). This is completed thanks to breathing, and to breathe we need the following structures (6).

The respiratory system is divided into two areas or levels: the upper respiratory tract and the lower respiratory tract. The upper respiratory tract is made up of the following:

Nose

- Nasal cavity: Also known as the nose, is the best entrance of air and where the inhalation starts. It contains hairs that clean the air.

- Oral cavity: Also known as the mouth, is another entrance for air. Mostly used when our nasal passages are functional, or we have a habit of breathing from the mouth.

- Sinuses: They are small cavities inside the face and the head, that are connected to the nasal cavity. They regulate the air that we breathe through our nose. Moreover, they control the temperature and the humidity of the breath.

- Pharynx (throat): A tube that passes the air that comes from the nasal cavity to the trachea.

- Larynx: Part of the breathing system that contains the vocal cords. When breath passes through these chords, the sound is formed.
- Trachea (Windpipe): A Tube that connects the pharynx to the lungs. It breaks down into two main bronchus. Each one goes to one lung. Inside the bronchial tubes, there are small filaments that have motion, which allows the mucous to go upward where it can be ejected. Bronchial tubes are divided in bronchioles, and bronchioles are divided in alveoli.

The lower respiratory tract is made up of the:

- Bronchi (Large airways)
- Bronchioles (Small airways)
- Alveoli: Small air sacs where the capillaries are contained. There are blood vessels that allow the exchange of oxygen and carbon dioxide. The pulmonary vein brings blood rich in carbon dioxide, and the pulmonary artery takes away blood rich in oxygen to the heart.
- Lungs: There are two lungs. One lung, the right lung, is sectioned into 3 lobes. The left lung is sectioned in 2 lobes.
- Pleura: A membrane that surrounds each lung and keeps a separation from the chest wall. A liquid called pleural liquid is in this separation to reduce the friction in the breathing process.
- Diaphragm: A muscle that separates the chest cavity from the abdominal cavity. This muscle's primary function is the generation of inspiratory flow (inhaling oxygen, exhaling carbon dioxide from the lungs).
- Complementary structures (5):

    - Muscles:
        - During inspiration: Secondary and external intercostal muscles such as the scalene, the pectorals, and the sternocleidomastoid.
        - During expiration: Anterior abdominal muscles. Secondary and internal intercostals such as the lumbar square and the sacrospinous.

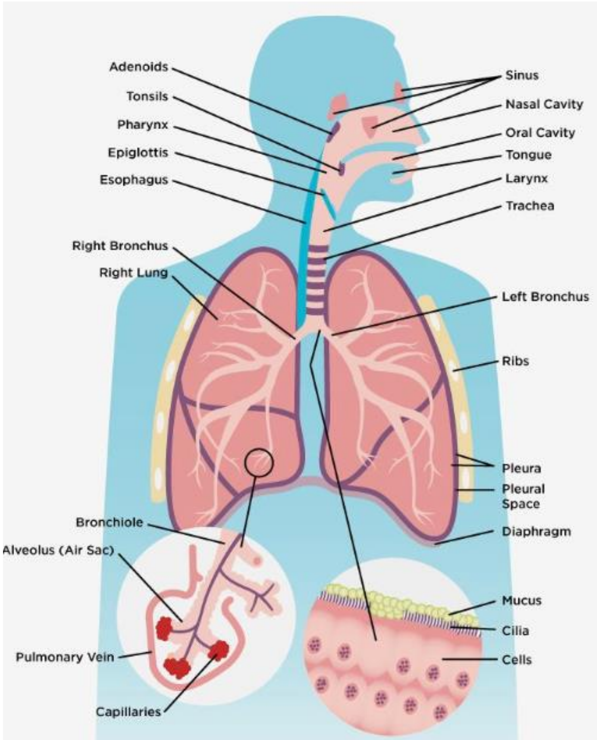

Figure 1: Structures of the respiratory system (6).

2.2. PULOMANARY VOLUMES

Air is a gas that flows from a place with higher pressure to a place with lower pressure. Breath happens because the air is a gas that senses a change of pressure that is made because of the respiratory system (5,7). The breathing process is divided into two phases (8) :

- Inhalation: The diaphragm contracts with the help of secondary and external muscles. This helps the thoracic cavity to expand, increasing its volume, and therefore the intrapulmonary pressure decreases. Consequently, this difference in pressure between the outside and the inside causes air to be rushed into the alveoli.

- Expiration: Air rushes out of the lungs with the relaxation of the diaphragm and the help of complementary muscles. This relaxation increases the interalveolar pressure and the thoracic volume.

Ventilation implicates three main pressures (7):

- Atmospheric pressure: Pressure in the atmosphere that comes from the weight of the atmospheric gases (9).
- Interalveolar or intrapulmonary pressure: This is the pressure inside the alveoli. During inhalation, it decreases as the thoracic cavity expands, allowing air to flow into the lungs. During exhalation, it increases as the thoracic cavity contracts, facilitating the expulsion of the air from the lungs (7).
- Intrapleural pressure: This is the pressure within the pleural cavity. It is always slightly negative compared to the atmospheric pressure. This negative pressure helps avoid a collapse and keeps the lungs inflated (7).

Aside from the aforementioned volumes, some other volumes and capacities are formed while breathing that are also relevant to the process of breathing. These are (5):

1. Tidal volume (TV): Inhaled air volume during inspiration or expiration during resting conditions.

2. Inspiratory Reserve Volume: The highest volume of air that a person can breathe in an inhalation.

3. Expiratory Reserve Volume: After a normal inspiration, the highest volume of air that can be exhaled. This volume of air is going to be higher than the inhaled volume of air.

4. Residual Volume: Volume that remains on the lungs after a forced breath. This volume prevents the lungs from collapsing.

5. Vital Capacity: After a forced inspiration, the highest volume of air that can be exhaled. The addition of tidal volume, inspiratory reserve volume and expiratory reserve Volume calculates the vital capacity. This volume allows us to identify respiratory alterations.

6. Total Lung Capacity, TLC: The sum of Vital Capacity and residual volume. Air volume that stays in the lung after a forced inspiration

7. Functional residual capacity: After a normal expiration, the air volume stays in the lung (5).

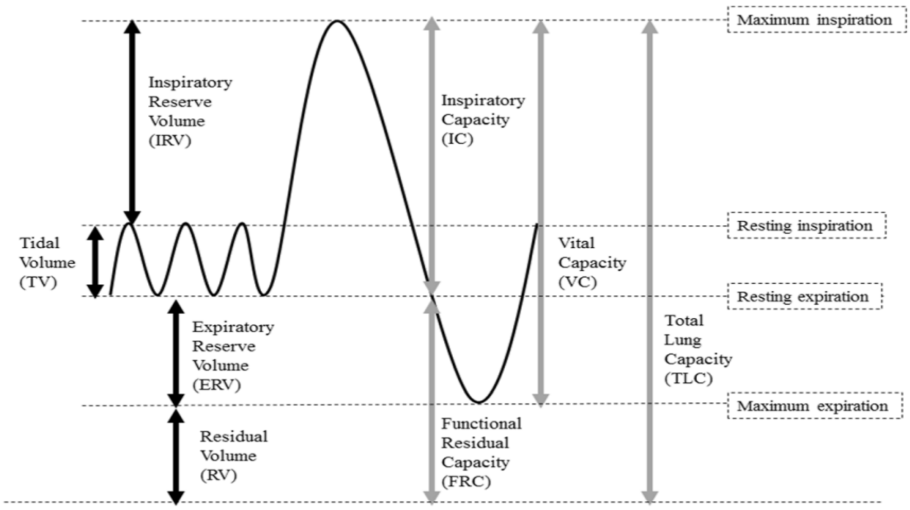

Figure 2: Volumes and capacity of the lungs (10)

2.3. PULMONARY VASCULARIZATION

Its principal function is to allow gas exchange and therefore transport oxygenated blood to the heart so it can pump it to different organs and maintain the vascularization of the organs.

From the right ventricle, non-oxygenated blood arrives at the lungs, transported by pulmonary arteries. The pulmonary arteries turn into arterioles and finally into capillaries that are located in the alveoli. Exchange of non-oxygenated blood and oxygenated blood is made and then, oxygenated blood is transported to the left ventricle through the pulmonary vein.

With the Ventilation/Perfusion (V/Q) ratio, the ventilation, and the perfusion of the vases of the patient are controlled. The health value of this ratio is 1, meaning that the zone of the lung that is being ventilated also has good blood vascularization (11).

2.4. INTENSIVE CARE UNIT

The intensive care unit (ICU) is a specialized ward that focuses on the management of critically ill patients, with specific trained nurses and physicians as well as curated ICU equipment (12).

Hospital care can be classified in different degrees, which are:

- Level 0: Normal hospitalization that does not require a monitorization of the patient or intensive care.
- Level 1: When patients need monitorization.
- Level 2: When patients need frequent monitoring and need continuous interventions to be made. An example would be a person who has an organ dysfunction. This hospital care can not be given in the previous hospitalisation levels.
- Level 3: When a patient needs life support intervention to be made. Cases like a person who has a multiorgan failure are classified in this group. A ward that will provide this continuous care is the intensive care unit. (13)

Moreover, it offers certain services that other wards can not have. These services are offered because the patient due to the critical condition that is in has to be continuously monitored. Also, the ratio of patients and healthcare professionals is lower because the patients are in such unstable conditions that it calls for specific, detailed, and more curated care.

There is a wide range of diseases that can be a cause of admission to intensive care admission. The admission into the ICU happens when there is an acute medical illness, an exacerbation of a chronic disease or postoperative care after major surgery (13).

Patients who are admitted to the intensive care unit must meet certain criteria. According to ICU guidelines, these are the recommended patients to be admitted into the ICU:

- A specific patient that can only be addressed in the ICU with life-supportive therapies.

- Patients who need life-sustaining interventions and have a higher probability of recovery.
- Critically ill patients who need hourly and/or invasive monitoring, such as continuous blood pressure monitoring via an arterial cannula.
- Patients who need life support for organ failure and intensive monitoring.

Life support interventions can be:

- Invasive ventilation
- Continuous renal replacement therapies
- Invasive hemodynamic monitoring
- Direct aggressive hemodynamic interventions
- Extracorporeal membrane oxygenation
- Intraaortic balloon pumps (13).

2.5. INVASIVE MECHANICAL VENTILATION

Invasive mechanical ventilation (IMV) is a respiratory support system that substitutes spontaneous breathing and is used to keep the lung function in patients who are under critical health conditions. This system helps the patient to breathe while taking over it (14,15).

The most common indications as to why a patient may need a breathing system can be (16):

- Low oxygen in blood
- Shortness of breath
- Help the patient’s body to recover or fight an infection, decreasing the energy a patient uses to breathe.
- Breathe while the patient's nervous system is injured and cannot breathe.
- Help when the patient has weak muscles to breathe.
- Breathe while the patient's body is fighting a drug overdose, a build-up of toxins or acute infections.

- Respiratory failure due to hypoxemia or respiratory distress syndrome.

The respiratory support system needs a ventilator and different items to set it up. To use a ventilator, it is needed to intubate the patient with an endotracheal tube. The endotracheal tube is used to remove secretions that the person cannot remove by itself, it protects the airway and allows making interventions, such as a bronchoscopy, with ease. Furthermore, a mixture of oxygen and air is pushed into the lungs. Depending on the pathology of the patient this mixture will be given programmed with certain characteristics. The ventilation is programmed taking into account the source of the critical state of the patient and how to improve it (15).

To programme the IMV there are two main variables to set up which are volume and pressure. Then other items are programmed, which are (15):

- Respiratory rate (RR): Number of times a person breathes in one minute. Adults cannot have a RR higher than 20 respirations per minute.
- PEEP: Positive expiratory pressure that allows the air sacs of the lung to not collapse at the end of the expiration.
- Peak pressure: The highest pressure that can be reached during inspiration (17).
- Plateau pressure: Pressure that the lungs have after inhalation and before expiration The basics of respiratory mechanics: ventilator-derived parameters.
- Tidal volume (Vt): The quantity of air that the ventilator pushes to the patient. It is measured with ml/kg.
- Flow rate: Parameter that targets the speed at which the Vt has to be entered.
- Total volume: The litres of volume that are introduced in the patient's lungs.
- FiO_2: The concentration of oxygen in the air that is being pushed into the patient's lungs.

- Trigger: It is a parameter sensible to the effort that the patient is making to initiate a breath on its own.
- Ti: Inspiration time.
- Cycle: The moment when a patient finishes the inspiration and before initiating the expiration.
- I:E ratio: Inhalation and expiration ratio programs, how many inhalations can be in an expiration. Normally the ratio is one inhalation and two expirations (1:2).
- Flow pattern: Parameter that controls how the breath is delivered. It can vary from a square flow waveform, sinusoidal flow waveform or descending flow waveform.

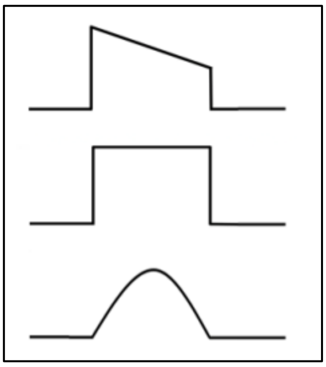

Figure 2. Representation of the delivered inspiratory flow waveforms (15).

- Descending flow waveform: This waveform in contrast to the square waveform allows to increase in the inspiration time and therefore allows the lungs to be more oxygenated. At the beginning, the flow is at peak and then it descends to a number near zero to maintain the established pressure as the respiration progresses. The pattern is commonly seen in pressure control mode.

- Square flow waveform: This pattern reduces inspiratory time, and it is used to extend the time of expiration in patients who are at risk of gas trapping and therefore causing auto-PEEP. Moreover, the tidal volume is delivered more rapidly, and this increases the time a patient can exhale. This flow in particular doesn't vary until the target volume is reached. This pattern is commonly seen in volume control mode.

- Sinusoidal flow waveform: This pattern is represented with a smooth curve because the machine controls the pressure, PEEP, and the flow is controlled by the person. In the beginning, the air gets in very slowly. As the breath progresses the flow goes faster till it reaches a high point, then the rate progressively decreases. The flow is seen in spontaneous breathing or people who are CPAP.

2.5.1. MECHANICAL VENTILATION MODES

Depending on the items that are chosen, the ventilation is going to be set up to do one thing or another. The following points are the main mechanical ventilation modes (18):

- Volume control mode: The volume is set up, but the pressure is not controlled. This mode can be controlled in two different ways(18):

    - Assist control: It substitutes completely the process of breathing. Patients in this mode must meet the set RR, which is why a trigger parameter is made to control whether the patient is breathing and is not doing apnoeas. In this mode of ventilation, these are controlled parameters: FiO_2, V, RR, PEEP, and Trigger.

    - Synchronized intermittent mandatory ventilation: Allows the patients to breathe on their own during a controlled time. In this mode of ventilation, these parameters are controlled: FiO_2, V, Fr de SIMV, PEEP.

- Pressure control: The pressure is set up and not the volume. This mode can be controlled in four different ways:
    - Assist Control: It substitutes completely the process of breathing. In this mode of ventilation, these parameters are controlled: FiO_2, P, RR, PEEP, and Trigger.

    - Pressure support: This mode is used when the patients are ready to try to breathe spontaneously.

    - SIMV: Controlled ventilation mode that allows the patient to take spontaneous breaths.

    - Pressure regulated/volume control: In this mode, the parameters that are controlled are the inspiratory time, the total volume, and the trigger. In this case, the ventilator to reach the set goal of total volume, sometimes changes the inspiratory pressure.

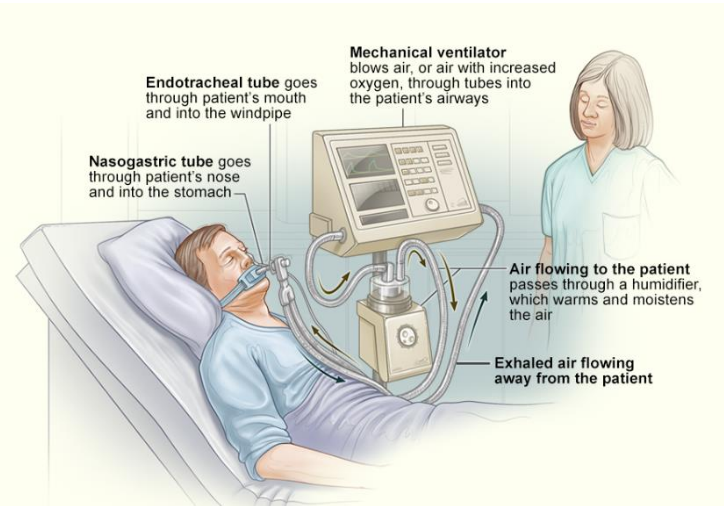

Figure 3: Graphic representation of invasive mechanical ventilation (19).

2.6. INTUBATION SECONDARY EFFECTS

Even though this system helps the patient maintain breathing, it can cause damage to the lung function (16). Secondary effects of using mechanical ventilation:

- Infections: The respiratory system is sterile. When we put an object that connects this sterile field into the non-sterile field it increases the risk of infection. And sometimes when we don’t take enough precautions a patient may contract an infection (16).

- Pneumothorax: The lung is weak and in consequence, it can develop a hole. That hole will leak air and will collapse the lungs (16).

- Dependency on mechanical ventilation. The person may not be able autonomously breath, despite all the treatments. At this point, it is discussed with the family the option of withdrawing the treatment because there will be no improvement (16).

- Lung damage: Sometimes the pressure and oxygen that the ventilator uses to keep the breathing causes damage. Too much pressure and oxygen are harmful to the lungs but can be reversible if the treatment works and recovers (16).

- Ventilator-induced lung injury (VILI): A delayed weaning can cause complications such as ventilator-induced lung injury (VILI), ventilator-associated pneumonia (VAP), and ventilator-induced diaphragmatic dysfunction (20).

2.7. WEANING PROCESS DESCRIPTION

Weaning is a process related to invasive mechanical ventilation (IMV). It is a gradual process in which mechanical ventilation begins to be withdrawn from the patient, to initiate spontaneous breathing and end extubating the patient. According to the research made by Hossam Zein et al. (21), it is calculated that 40% of the time that a patient is connected to the IMV, it is aimed at the weaning phase. This means almost half of the time of the MV process is spent just trying to remove it.

To begin this process the patient has to meet certain health criteria, so the process does not cause an injury. This process can be really short or can last days to weeks. During this process, the need for assistance of different healthcare workers such as physicians, nurses, physiotherapists, and dieticians, is needed (22).

During the weaning process, there are critical steps that need to be taken. Firstly, the patient has to be ready to be weaned from IMV. Then the patient has to tolerate positively the weaning to be extubated. Moreover, different parameters are taken into account while the process is going on. The Rapid Shallow Breathing Index (RSBI) is a test created by Yang and Tobin, to measure the ratio between the RR and the VT and a positive result is correlated with a successful weaning. A score higher than 105 is related to weaning failure. Also, a cuff leak test is done to ensure that the patient has an adequate gas leak to ensure that there is no presence of significant oedema (23).

Because the information on the criteria to start this process and extubate is very diverse, research about this theme was made. Concepts related to weaning and when to extubate the ICU patient, are further researched in this bibliographic review.

3. OBJECTIVES

The bibliographic review has established 5 aims such as:

General objective:

- To determine the extubating criteria in the weaning process

Specific objectives:

- To know the criteria to identify weaning tolerance.
- To relate the weaning process and IMV outcomes.

3.1. SUSTAINABLE DEVELOPMENT GOALS (SDGS)

- Health and well-being objective. This objective is related to this bibliographic research because the ultimate goal of this project is to ensure the patient's well-being. Moreover, different options are being found to improve the patient's mortality prognosis and the patient's lifestyle. As the objective states, the basis of a healthy economy is a commitment to the health of the person.

4. METHODS

4.1. INCLUSIVE CRITERIA:

- Scientific studies published between a 10-year range: From 2015 until 2024 both included.
- Articles published in the following languages: English, Catalan and Spanish.
- Articles that include the following keywords: Ventilator weaning, airway extubation, invasive mechanical ventilation, intensive care unit and patient selection.
- Articles that have full accessibility.

4.2. EXCLUSIVE CRITERIA

- Studies that include paediatric patients.
- Articles that include non-invasive mechanical ventilation in the study.
- Studies that are conducted with patients who are treated in different healthcare areas, not ICU area.
- Articles that the aim of the study is based on a pathology or intervention.
- Articles that include tracheostomy.

4.3. ALGORITHMS OF BIBLIOGRAPHIC RESEARCH

The bibliographic research was conducted with the following search databases: Pubmed, Scientific Electronic Library Online (SciELO) and ScienceDirect. To do the algorithm research these were the MESH terms and keywords used: “Ventilator weaning”, “airway extubation”, “invasive mechanical ventilation”, “intensive care unit”, “patient selection”, “paediatric” and “tracheostomy”. To find the articles the operators used were: “AND”, and “NOT”. A flow diagram was created and implemented in each database (Figure 4).

Figure 4: Algorithm research followed in ScienceDirect, PubMed and Scielo

5. RESULTS

5.1. TABLE 1: SUMMARY OF ARTICLES FOR THE BIBLIOGRAPHIC REVIEW

Database	Author/s	Title	Year of publication Journal title	Method of research	Conclusions
Scielo	Hernández-López G.D. et al.	Retiro de la ventilación mecánica	2017 May 5th Medicina crítica (Colegio Mexicano de Medicina Crítica)	Analytic and descriptive	An effective collaboration with the interdisciplinary team enhances the quality of care and patient safety, improving extubation outcomes. Extubation is not risk-free, so it is important to ensure that the extubation strategy is low-risk and the patient suffers minimal discomfort. In addition, it is important to optimize airway access, oxygenation, and ventilation.
PubMed	Pham T. et al.	Weaning from mechanical ventilation in intensive care units across 50 countries (WEAN SAFE): a multicentre, prospective, observational cohort study	2023 May The Lancet: Respiratory Medicine Volume 11 number 5	Prospective observational and cohort study	Across different countries, different criteria are used. In this article, recent studies from 50 countries are reviewed to identify different weaning predictors, criteria and procedures in a patient who is assisted with invasive mechanical ventilation.

PubMed	Kenichi N. et al.	A comprehensive protocol for ventilator weaning and extubation: prospective observational study	2019 Journal of Intensive Care	Prospective observational and cohort study	In this article, it is shown that during the weaning process in mechanical ventilation, the rates of post-extubation respiratory failure (PERF), reintubation, and hospital mortality decreased with the use of a standardized protocol.
ScienceDirect	Paulo A.F. et al.	Weaning failure and respiratory muscle function: What has been done and what can be improved?	2017 Respiratory Medicine	Review article	This project aims to identify the evidence to assess the readiness of extubation. Identifying respiratory muscle weakness in critically ill patients shows good accuracy. It is encouraged to practice programs that include IMT, SBT, non-invasive MV and early mobilization.

ScienceDirect	Onrubia X, Roca de Togores A.	Can intubate but cannot extubate: A practical narrative review on extubation.	2023 Trends in Anaesthesia and Critical Care	Narrative review	The study concludes that the following criteria should be checked to do a good assessment for a safe extubation: • Optimisation of physiological, postural and analgesic conditions. • Review the pathological factors that lead to poor extubation conditions. • Use of scoring scales or assessment tests
PubMed	Zein H. Baratloo A., Negida M., Safari S.	Ventilator Weaning and Spontaneous Breathing Trials; an Educational Review	2016 Archives of Academic Emergency Medicine	Educational review	The study acknowledges that the SBT should begin with treating the underlying cause of respiratory failure and take into account the weaning predictors because they are parameters that intervene in the IMV outcomes.

PubMed	Riddhi Kundu, et al.	Integrated ultrasound protocol in predicting weaning success and extubation failure: a prospective observational study.	2022, January Anaesthesiol Intensive Ther	Observational study	The study concluded that the use of an ultrasound protocol taking into account the lung, diaphragm, and cardiac sonography could predict weaning failure.
PubMed	Vahedian-Azimi A., et al.	Protocolized ventilator weaning versus usual care: A randomized controlled trial	December 2020 Internation Journal of critical illness & injury science	Randomized controlled trial	A protocolized weaning is associated with a decrease in re-intubation, shorter hospital stays and patient mortality.

5.2. DESCRIPTION OF THE RESULTS

Focusing on the main objectives that were formulated in the 3rd section, this literature has been found to complete the bibliographic review. Moreover, a summary of each article is made after a detailed reading, so that the results and explanations are shown, and further discussion can be made.

1) This descriptive-analytical study conducted by **Lopez H.D.G. et al.** (2017) (24), aims to find different recommendations that establish a pattern to extubate the patient, avoiding extubation failure and reintubation. Through the study of the literature related to the concepts described above, some suggestions are formulated. It is confirmed that to perform extubation, the patient requires an adaptation time to weaning that represents up to 40 or 50% of his intubated time. It must be taken into account that the patient can be classified into three groups according to the difficulty and duration of weaning:

- Simple: A patient who tolerates one spontaneous breathing trial (SPT) and is successfully extubated for the first time.
- Difficult: A patient who does not tolerate the first spontaneous breathing trial and has to do three SPTs or spend less than seven days doing breathing trials to be successfully extubated.
- Prolonged: A patient who does not tolerate the first spontaneous breathing trial and has to do more than three SBTs or more than seven days doing breathing trials to be successfully extubated.

The article agrees that IMV must be removed as early as possible. Resources before weaning must be used to indicate that the patient is prepared for extubation. These determinants have an important value in terms of the prognosis of extubation, and they are the following ones:

- Before starting weaning, it is necessary to rule out that the person does not have injuries in the laryngeal area. The injuries make the breathing process difficult and therefore increase the risk of extubation failure. To ensure this does not happen, a volume leak test can be done.

- The maximum pressure generated during an inspiratory effort is frequently used to evaluate respiratory muscle strength. This pressure has a negative value and under normal conditions, the human being can reach a higher IPmax. than 100 cmH_2O and requires the effort and cooperation of the patient, making it sometimes difficult to obtain an adequate measurement. However, Truwit and Marini do not depend on the patient's cooperation. It consists of obstructing the airway between 20 and 25 seconds, forcing the patient to exhale but not inhale and then after leaving the patient makes a great effort to inhale. If the maximum inspiratory pressure indicates that extubation would be successful, it will have a value between 20 and 30 cmH_2O.

- Airway occlusion pressure: Pressure that occurs during inhalation when the airway is obstructed. Like the maximum inspiratory pressure, it has a negative value.

- Vital capacity: Strength of the muscles that interact in breathing and impedance of the respiratory system. It depends on the patient's effort and the approximate value is 65 and 75 ml/Kg. If the value is greater than 10 ml/kg, extubation is more likely to be successful.

- The volume per minute is the total volume inhaled in litters per minute. If the parameter in the IMV is less than 10l/min, the chances of extubation being successful are higher.

- Shallow breathing index (SVR) or Yang and Tobin index: Calculates the probability that extubation is successful. To calculate this index, the quotient of the respiratory rate per minute and the tidal volume in litres must be calculated. A rate greater than 106 breaths per minute indicates a high probability of extubation failure. On the other hand, a rate of less than 60 breaths per minute indicates a high probability of success in extubation. It should be noted that although this index has a high sensitivity and is the most accurate predictive index, its specificity is less than 50%.

- Lung and diaphragmatic ultrasound

Afterwards, a spontaneous breathing test should be done. The spontaneous ventilation test involves keeping the patient breathing with little respiratory support, such as non-invasive ventilation (NIV), or with an endotracheal T-tube, for approximately 30 minutes. It should be considered that the use of NIV cannot be daily.

This is necessary to understand if the patient is tolerating the weaning process and therefore a series of criteria must be met, which are the following:

- PaO_2/FiO_2 ratio ≥ 200 or $SatO_2$ ≥ 90% with FiO_2 ≤ 0.40 and PEEP ≤ 5 cmH_2O.
- Hemodynamic stability, that is, it does not require vasoactive medication and therefore the patient does not present hypotension and the temperature remains at a value less than 38ºC. If vasoactive medication is required, it should be dobutamine at a dose of less than 5 mg/kg/min.
- Regarding consciousness, the patient must be awake or easily awakened.

This study emphasizes at one point that weaning protocols should be made in the ICU, in which different health professionals must participate. The study claims that to perform a good extubation and improve patient safety, good multidisciplinary collaboration is required. This will improve the results, allowing professionals to identify patients ready to be extubated sooner and therefore reducing their time connected to IMV. Although we take many factors into account before performing the extubation and ensure a low risk of failure, there will always be the possibility that it will fail and therefore the patient will need reintubation.

2) The study made **by Pham T. et al**.(25) is a multicentred, prospective, observational cohort article. This cohort study's main objective is to describe the management and the epidemiology of the weaning process in different regions and how it impacts the outcome of the patients. They observed the outcome and methods and techniques that were used in the process of extubation, with patients who were intubated with mechanical ventilation, in the intensive care unit, across 50 countries. For assessment of the physical state of the patient, they classified patients taking into account their frailty. There were 4 levels of frailty: Mild, moderate, severe, or very severely frail.
The parameters that were considered to observe the differences were the following:

1. Methods and techniques used for weaning.

2. Frequency and duration of spontaneous breathing trials. Any attempt to wean the patient off MV was considered a spontaneous breathing trial or a direct extubation if there was no transition.

3. Sedation strategies during the weaning process. They classified the different stages of consciousness such as awake, moderately sedated, and deeply sedated patients.

4. Use of protocols.

5. Prevalence of complications during weaning, such as reintubation and tracheostomy.

6. Patient outcomes following weaning, including mortality rates and length of ICU stay. Extubation success was considered in any patient who was without intubation for 7 days or who was discharged from the intensive care unit without IMV.

Parameters such as the SOFA score were not evaluated since no records of this were found in the different regions and therefore a comparison could not be made.

The results were classified as follows:

- The no separation attempt group: Patients who never had a separation attempt.
- Short wean group: Patients who were weaned 1 day after the first separation attempt. 64,7% of the patients
- Intermediate wean group: Patients who were weaned for more than 1 day but less than 7 days. 10,1% of the patients.
- Prolonged wean group: Patients who were successfully weaned at least 7 days after the first separation attempt and up to 90 days after intubation. 65% of the patients. 9.6% of the patients.
- Failed wean group: Patients who underwent a separation attempt and had to maintain the intubation at day 90 or more. Also, patients who got transferred out of the intensive care unit or died without a successful weaning.15,6% of the patients.

It was observed that 22,4% had a delay of five or more days in starting the weaning process. Moreover, according to this article, sedation management is a big factor in weaning because a higher sedated patient is directly related to a higher chance of weaning failure.

Also, in the results, it was observed that the factors associated with extubation failure, that had at least one attempt to separate the IMV, were:

- The high age
- Immunocompromised people
- The fragility

There were several differences in sedation and withdrawal strategies in the spontaneous breathing trials. Therefore, the conclusion was that there is a need to create and investigate more in this research field to standardize weaning protocols. This causes an improvement in the results of the weaning process therefore reducing the percentage of extubation failures and avoiding complications such as reintubation or tracheostomy.

3) In this prospective observational study made by **Kenichi N. et al.** (26), a group of patients admitted to the intensive care unit who are on mechanical ventilation are studied to be able to formulate an extubation protocol, considering the weaning process.

This study selects 646 patients who require IMV and who were admitted to the ICU. Of these, 398 patients were discarded, since, 48 hours after their extubation, they died, removed the endotracheal tube themselves, or had to be transferred to another service or hospital. Of the remaining 248 patients, a continuous assessment was performed following the same parameters, to protocolize weaning.

Before extubation, the following parameters are constantly monitored:

- Heart rate, mean arterial pressure and respiratory rate.
- Glasgow Coma Scale score
- Arterial blood gas (ABG) analysis
- Acute Physiology and Chronic Health Evaluation (APACHE) II score
- Sequential organ failure assessment score under tracheal intubation (SOFAT score)
- Rapid shallow breathing index (RSBI)

This checklist allows us to ensure, at a minimum, that the patient is at risk of extubation failure. The risk factors are:

- Tolerance of spontaneous breathing trial (SBT): The patient breathes spontaneously for 30 minutes without the trigger activated, with a PSV of 0, and a PEEP of 5 cm H2O. To confirm that the patient tolerates SBT, the following must be observed:
    - That the RR is greater than 35 breaths per minute for 5 minutes or more.
    - That the RSBI more commonly called the Yang and Tobin index, is more than 100 cycles/min/l.
    - That the saturations are less than 90% for 5 minutes or more

- That the heart rate is greater than 120 rpm or that the frequency is 20% higher than your usual heart rate.
- A systolic blood pressure of less than 90 mmHg or greater than 180 mmHg is observed for 5 minutes or more.
- Presence of chest pain or a variation in the electrocardiogram
- Presence of respiratory distress such as dyspnoea, anxiety, or diaphoresis.

If they meet any of these criteria, they must be re-evaluated until the next day, since the patient has not tolerated SBT and therefore is not a candidate for extubation.

Eligibility for extubation: Once the patient has met the previous parameters, they must meet the second evaluation, by passing seven points that will allow them to advance with the extubation process.

- The patient does not present a severe loss of consciousness.
- Cough reflex present.
- Present hoop reflex
- Cardiovascular system that does not depend on dopamine levels higher than 5 micrograms/kg/min.
- Respiratory rate lower than 120 bpm.
- Electrocardiogram that reflects a constant rhythm and that does not reflect the presence of arrhythmias or ischemia.
- Respiratory rate lower than 35 breaths per minute
- RSBI lower than 100 breaths/min/L
- Presence of leak in the leak test

Patients who meet these criteria and pass both points 1 and 2 are extubated. If this is not the case, the patient is reviewed and evaluated again with the previous points.

Evaluation after extubation: The extubation is not considered a success until approximately 48 hours have passed after extubation. The criteria that must be considered and that indicate a possible reintubation are:

- RR greater than 35 breaths per minute for 5 minutes or more
- Saturations less than 90% for 5 minutes or more
- Heart rate greater than 120 beats per minute or the rate is 20% higher than your usual heart rate.
- A systolic blood pressure of less than 90 mmHg or a decrease of 30 mmHg below its usual pressure is observed for 5 minutes or more.
- Presence of chest pain or a variation in the electrocardiogram
- Presence of respiratory distress such as dyspnoea, anxiety, or diaphoresis

Patients who meet one of these criteria require ventilatory support. The use of non-invasive positive pressure ventilation (NPPV) should be evaluated. If not indicated, evaluate tracheal intubation. Doctors will check all these criteria 60 minutes after extubation, during the morning and afternoon/evening. The ICU nurses observe that the patient is hemodynamically stable and that vital signs are maintained without any alteration considering the previous criteria. Post-extubation respiratory failure, PERF, was observed in these cases:

- When reintubation was performed on the patient before the 48 hours after the first extubation.
- When the patient requires more than 48 hours of prophylactic NPPV
- When 48h after the extubation the patient required the use of a rescue NPPV under conventional oxygen therapy

4) This article made **by Paulo A.F. et al.** (27)**,** reviews literature on weaning and what aspects they all have in common to achieve a successful weaning.

First, it describes the criteria that must be taken into account for the patient to be a candidate for extubation. These are:

- Rapid shallow breathing index: This index tells us how likely it is that weaning will be successful. To calculate it, the quotient of the respiratory frequency and the tidal volume is made. According to this article, although its specificity is low, if the patient has an RSBI index of less than 105, there is a high probability that weaning will be successful. This index concludes that if there is good compliance that is related to good gas exchange, the person will be able to maintain SBT. The Thoracic Society/American College of Chest Physicians recommend that SBT should be conducted with inspiratory pressure augmentation rather than without (for example, using a T-piece or a CPAP)

- Maximal inspiratory pressure: Also known as negative inspiratory pressure, it occurs when the patient makes excessive inspiratory effort during a forced inspiration. This indicates the muscle force during inspiration. Furthermore, it does not require the patient's cooperation. It is a parameter that is not commonly used and therefore will be used depending on the professional's criteria. To measure this parameter, the patient must be kept monitored. A one-way valve will be placed in the patient's MV first, which does not allow him to inhale but does allow him to exhale and then after 12 to 15 seconds and a maximum of 25 seconds a forced inhalation can be done. To ensure that the values obtained are reliable, it is necessary to make a minimum of 3 attempts. The value that we will take as the final result is the highest inspiratory pressure. If the final value is greater than -30 cmH_2O (that is, a more negative value) it indicates that the patient is probably not ready to begin weaning.

- Measurement of diaphragm function: If we observe through an ultrasound that the volume of the diaphragm has decreased, this indicates that there is weakness in respiratory strength. This parameter could be a new indicator that allows us to know whether the person is prepared to undergo the weaning and extubation process.

- Tension–time index of the diaphragm: This index evaluates the capacity of the diaphragm and is a priority indicator to know if weaning will be a success or a failure. It tells us the respiratory load and whether the patient's respiratory pattern is sustainable. To calculate this index, the average trans-diaphragmatic pressure for each breath must be multiplied by the maximum trans-diaphragmatic inspiratory pressure and the inspiration time multiplied by the time it takes to complete a respiratory cycle. To obtain these data, an invasive test must be performed in which 2 balloon catheters are placed in the stomach and the oesophagus. Even so, it can be calculated non-invasively, taking into account the respiratory pressures and not the diaphragmatic pressure.

To do a good weaning, the article recommends following a hospital protocol that includes the following actions:

- Early mobilization: Postural changes and mobilizations are actions that help the patient have better results in the weaning and extubation process.

- The spontaneous breathing trial: It is recommended to do the weaning process using the T-Tube or the PSV, as it improves the extubation success rate. However, this does not indicate that there are significant differences between the PSV and the T-Tube in terms of weaning success, intubation, or mortality in intensive care units.

- Non-invasive ventilation: In patients where it is observed that the weaning process is not having an improvement, it is recommended to use non-invasive mechanical ventilation. It allows there to be an improvement in gas exchange, reducing respiratory force and improving tidal volume. This reduces the chances of intervening with a tracheostomy, reducing the risk of pneumonia and weaning failure.

- Inspiratory muscle training: This action is still being investigated but may be an option in case the patient is not responding positively to weaning. Studies regarding this action have only been done in people who have already failed in weaning. This could be an action that helps improve the success of extubation. To do this exercise you must set the VMI to the following parameters:

    - Adjustment of ventilator trigger sensitivity (AVTS) to 20–40%
    - Inspiratory pressure that is within a range of 20 and 50%

- During this process, continuous monitoring of the patient is necessary since in many cases the trials are interrupted due to desaturation or tachypnoea.

The results of these studies indicated a correlation between the improvement of inspiratory capacity and respiratory muscle strength. This helped improve the chances of extubation. However, a decrease in days with invasive mechanical intubation was not observed.

This article ends, by confirming that we must have a standardized protocol to ensure that all possible actions are followed to improve extubation success and emphasizes the professional's judgment in these situations.

5) According to the article made **by Onrubia X. et al.** (28), “The Canadian Airway Focus Group”, there are situations that must be taken into account since there is a high risk that extubation will fail. The first case is when the patient does not tolerate weaning correctly. The second case is when the intubation has been difficult.

Some characteristics are not the main ones, but that can increase the risk of extubation failure, such as:

- Muscle weakness, or poor muscle strength, related to the underlying pathology or related to the administration of sedative medication.
- Pulmonary oedema or upper respiratory tract oedema
- Obesity, gastric distension or cardiovascular diseases
- Hypothermia, uncontrolled pain and imbalance in the pH, acid-base, of the blood.
- Practice of surgeries that put the patient at risk or susceptible to possible intraoperative haemorrhages.
- Features like clenching the teeth to the tube

The article, to prevent extubation failure, mentions that oedema in the laryngeal area is a major indicator of extubation failure. Among the cases of extubation failure, it was observed that 26% of patients presented oedema, which caused re-intubation. For this reason, it has been observed that to prevent post-extubation problems, corticosteroids, such as dexamethasone, hydrocortisone or methylprednisolone, should be administered 12 to 24 hours after extubation, as a preventive measure, so that in the event of an oedema, this is reduced. Another measure would be to observe with a laryngoscopy or video laryngoscope if the larynx is inflamed. An indicator that can also indicate whether the patient is ready for extubation is the Yang-Tobin index.

Finally, the study recommends a standardized protocol should be followed during the extubation process, taking into account the criteria of each professional, the condition and pathologies of the patient and its context. It is also recommended to do a spontaneous breathing trial to avoid the risk of extubation failure. However, it emphasizes that it should not be the only factor when considering extubation.

6) This study, made **by Zein H. et al**.(21), main objective to review the main aspects that should be considered, during the weaning, to successfully extubate ICU patients.

A few of the negative weaning predictors were:

- Heart rate variability: If the heart rate decreases during spontaneous breathing trials, this increases the chances of extubation failure. Even so, the article states that more studies are still needed in larger groups of people.
- Diaphragmatic dysfunction: The fact that VMI is used for a long time negatively affects the diaphragm, thus losing its strength. The functioning of the diaphragm can be checked during breathing. If a decrease of more than 30% in muscle strength is observed, this indicates that the chances of extubation failure are greater.

According to the article, the indicators that indicate that a patient is prepared for weaning can be classified as:

Subjective assessment

- Withdrawal of neuromuscular blockers
- Decrease of disproportional trachea-bronchial secretions
- Resolution of the main cause of intubation

- Withdrawal of sedative drug infusions
- Adequate cough

Objective measurements:

- Rule out cardiovascular diseases like myocardial ischemia.
- The heart rate is 140 beats per minute or lower.
- Suitable haemoglobin level (≥ 8 g/dl).
- Systolic blood pressure between the numbers of 90 and 160 mmHg.
- No presence of higher temperature than 38ºC.
- Presence, of minimal infusion of vasopressors or inotropes. (< 5 µg/kg/minute dopamine or dobutamine)
- No presence of infusion of vasopressors or inotropes.

Related to oxygenation we have the following indicators:

- Tidal volume > 5 mL/kg
- Vital capacity >10 mL/kg
- No excessive inspiratory effort
- Respiratory rate of 35 breaths per minute or less.
- PaO_2 of, or, higher than 60 mmHg and $PaCO_2$ of or, lower than 60 mmHg
- PEEP of 8 cmH_2O or lower
- No presence of respiratory acidosis (blood pH ≥ 7.30)
- O_2 saturation higher than 90% with a programmed FIO_2 of 40% or lower.
- Rapid Shallow Breathing Index lower than 105 breaths/min/L. It is the quotient of the respiratory rate and the tidal volume.

This article also points out different weaning strategies and defines their steps:

Spontaneous breathing trial:

- SBT Duration: The trials can not be lower than 30 minutes and not higher than 120 minutes. Also, at the beginning of the trial physicians should assess the first minutes of the trial to observe how the person reacts so the trial can continue.

Step 1: Asses which strategy the patient can use. These are the main strategies.

- T-piece trial: A T-piece is connected to the endotracheal tube and through it, oxygen is supplied.
- Continuous positive airway pressure (CPAP) trial with the same PEEP that the patient used.
- Invasive ventilation with a low level of pressure support (5-8 cmH_2O). Patients who use this strategy tend to have a more successful weaning process than patients who use T-piece.

Step 2:

Once we reach this step, extubation must be considered. But if the first step did not have a positive result, the following options must be followed:

- Evaluate other causes of respiratory failure.
- Assess the use of respiratory parameters that do not weaken the respiratory system.
- Evaluate the spontaneous breathing test every 24 hours.

Criteria of successful spontaneous breathing trials that indicate good tolerance to spontaneous breathing trials:

- Respiratory rate lower than 35 breaths/minute
- Heart rate lower than 140 beats per minute
- Arterial oxygen saturation >90% or PaO_2 > 60 mmHg on FiO_2<0.4
- 80 < Systolic blood pressure < 180 mmHg or <20% change from baseline
- No signs of increased work of breathing or distress. Indicators of distress can be the use of accessory muscles, paradoxical or asynchronous rib cage abdominal movements, intercostal retractions, nasal flaring, profuse diaphoresis, and agitation.

7) The objective of this study, made **by Kundu R. et al.** (29), is to identify which are the parameters that lead the patient into a weaning failure during the spontaneous breathing trials. According to the study, the SBT happens when the patient has been stabilised and the main pathology has been resolved. Moreover, the SBT typically lasts 30 to 120 minutes a day, to ensure that the patient is ready for extubation. According to the study, the parameters that should be considered are pulmonary and cardiac function. Because of the main objective, this study aims to identify the alteration of these parameters by using bedside ultrasonography.

In the study, a physician scans the thorax, before and after the SBT, and measures the lung ultrasound score (LUS) and the diaphragm thickening fraction (DTF). Three measurements are done to achieve a reliable number. 60 patients participated and they were divided into Group F and Group S. Group S (n=33) is the group that had a successful weaning and extubation. And group F (n=27) is the group that had a weaning failure. It was shown that group S, which was successful, had a lower LUS, before and after the SBT. Moreover, the DTF was higher, before and after SBT, with the successful group. The patients in Group F had a higher LUS and a lower DTF than those in Group S.

The study concluded that a high LUS will likely lead to respiratory distress and a DTF lower than 26% is a predictor of weaning failure. Moreover, SBT was associated with loss of lung aeration, because the LUS before SBT was lower than the LUS after the SBT, in both groups S and F.

Even though the use of this technique is important, extubation should not be solely based on this parameter. An interdisciplinary team view is also needed and with it, the usage of other weaning parameters to reach the best consensus. The study recommends that these parameters should be checked in the weaning phase before an extubation is made. If alterations are found, the patient can receive inspiratory muscle training.

8) According to this article, conducted **by Azimi V. et.al.** (30), it has been demonstrated that a successful SBT is directly related to weaning success. Ventilator weaning is a necessary procedure to extubate a patient, but it is a procedure that is still in debate because of the different points of view to proceed with it. It is important to wean patients from the ventilator as soon as possible to reduce complications. An SBT with a duration of between 30-120 min, results in IMV extubation success of 77%.

It is important to know when and how weaning must be proceeded with. Because of this, in this prospective, multicentre, randomized controlled trial study, it is discussed if a protocolized weaning (PW) strategy has better outcomes than a usual care (UC) weaning. 7750 patients were screened, and 4200 participated in the study. PW group or group 1 had 2075 patients. UC group or group 2 had 2125 patients. The PW group followed the following criteria:

- Efficacy of airway protection.
- Presence of a good mental status and adequate gag reflexes and cough reflexes.
- Cleanse secretions and a decrease in secretion (secretion cleanse is made no more than every 2 h)
- Level of FiO_2 of 0.4 or less.
- Continuous positive airway pressure with a pressure of 5 cm H_2O
- Haemodynamic stability without the presence of vasopressors or inotropes, and mechanical devices such as an intra-aortic balloon pump.
- Signs of respiratory distress
    - Respiratory rate higher than 30 breaths/min
    - $SatO_2$ <90%
    - Heart rate (HR) >140 beats/min
    - Systolic blood pressure higher than 200 mmHg or blood pressure lower than 80 mmHg
    - Presence of agitation, anxiety, or diaphoresis.

The UC group followed the following criteria:

- SBT type and extubation decision were determined by the physician on service taking into account the following:
    - Neurologic status
    - Airway competence (presence of gag, cough, and suction requirements)
    - Respiratory parameters, including the RSBI.

In this article, extubation success was defined as when the patients can remain extubated for more than 48 hours after their extubation. The main results were:

- Forty-eight-hour re-intubation rates were lower in the PW versus UC groups.
- Re-intubation rates ≥48-h postextubation were lower in the PW group.
- No significant difference in mortality was shown between the groups.

In conclusion, a decrease in re-intubation rates improved with PW and no mortality difference between the groups was observed.

6. DISCUSSION

The starting point of this review was to understand how the weaning process happens to extubate a patient successfully. The weaning process has to be a gradual de-escalation made with spontaneous breathing trials and it has to last for more than 30 minutes and less than 120 minutes. The SBT is done with NIMV or a T-tube. Pharm et al. (2018) (27) recommend carrying out the SBT with a T-tube or a PSV, discarding NIV as an option for weaning. Different literature supports this affirmation as, T-Tube and PSV techniques, increase the success of extubation. Furthermore, it cannot be said which is, between T-Tube and PSV, the better option, as the literature supports that the difference between them is not very significant. Although 6th article mentions that PSV with a low level of pressure tends to have a more successful weaning outcome than using a T-piece.

Secondly, Hernández-López G.D. et al. (2017) and Pham T. et al. (2023) (25,31) classify together the weaning and extubating procedures. This classification considers the time the patient has been intubated and the number of attempts of extubation. Pham T. et al. (2023) (25) add a fourth group, which is a group of patients who did not go through the weaning process. Because it does not include the weaning process the group can not be included in the weaning and extubation classification.

Through the Hernández-López G.D. et al. (2017) article (31), the weaning process breaks down into different parameters that will help the patient be extubated. These parameters must be followed since they have a high prognostic value. Before starting weaning, it must be ruled out that the person does not have injuries in the laryngeal area. The cuff leak test is a good method to ensure that the person does not have injuries. It is also recommended, according to the Kenichi N. et al. (2019) article (26), to make sure that before starting the weaning, there is continuous monitorization of the vital signs, there is an evaluation of the level of consciousness (Glasgow Coma Scale) (25,26) and the arterial blood gas is analysed. Moreover, it is recommended, to use different test scores such as the acute Physiology and Chronic Evaluation Health (APACHE) II score, the sequential organ failure assessment score (SOFAT score), and the Rapid shallow breathing index (RSBI) for a more optimal assessment.

The Zein H. Baratloo A., Negida M., Safari S. article (2016) (21)**,** classifies the weaning criteria into three groups that assess different sides of the procedure. The Subjective assessment includes the withdrawal of neuromuscular blockers, a decrease of disproportional trachea-bronchial secretions, the withdrawal of sedative drug infusions, an adequate cough reflex and the resolution of the main cause of intubation. The objective assessment consists of determining that cardiovascular disease does not exist, that the heart rate is 140 beats/minute or lower, the haemoglobin level is ≥ 8 g/dl, a systolic blood pressure between the numbers of 90 and 160 mmHg and no presence of higher temperature than 38ºC, or of infusion of vasopressors or inotropes. This last parameter can differ slightly as a minimal infusion of vasopressors or inotropes can be present. Moreover, there is a classification that includes respiratory parameters and assesses the respiratory capacity of the patient. A tidal volume that is higher than 6 mL/kg, a vital capacity higher than 10 mL/kg, no presence of excessive inspiratory effort, a respiratory rate is 35/minute or less, the PaO_2 is 60 mmHg or higher, the $PaCO_2$ is lower than 60 mmHg, the PEEP is 8 cmH_2O or lower. Furthermore, rule out the presence of respiratory acidosis (blood pH ≥ 7.30), have an O_2 saturation higher than 90% with a FiO_2 of 0.4 or lower, and a Rapid Shallow Breathing Index lower than 105 breaths/min/l.

A good tolerance of the weaning process can be observed through good monitoring and the evaluation of the right criteria. The Kenichi N. et al. (2019) article (26) indicates that a good tolerance of the SBT is when a patient breathes spontaneously for 30 minutes without the trigger activated, a PSV of 0, and a PEEP of 5 cm H_2O. If the patient has tolerated positively the SBT the patient will express the following parameters:

- Respiratory rate lower than 35 breaths/minute
- Heart rate lower than 140 beats per minute
- Arterial oxygen saturation >90% or PaO_2 > 60 mmHg on FiO_2<0.4
- 80 mmHg < Systolic blood pressure < 180 mmHg or <20% change from baseline
- No signs of increased work of breathing or distress. Indicators of distress can be the use of accessory muscles, paradoxical or asynchronous rib cage abdominal movements, intercostal retractions, nasal flaring, profuse diaphoresis, and agitation.

To observe if the patient presents any difficulty during the SBT, the patient needs to meet any of these criteria.

- RR is greater than 35 breaths per minute for 5 minutes or more.
- RSBI, more commonly called the Yang and Tobin index, is more than 100 breaths/min/l.
- Saturations are less than 90% for 5 minutes or more.
- Heart rate is greater than 120 rpm or that the frequency is 20% higher than your usual heart rate.
- A systolic blood pressure less than 90 mmHg or greater than 180 mmHg is observed for 5 minutes or more.
- Presence of chest pain or a variation in the electrocardiogram
- Presence of respiratory distress such as dyspnoea, anxiety, or diaphoresis.

IMV weaning is a necessary procedure, but the ways to practice it change depending on the clinicians' view and the hospital protocols, making it a present debate (30).

It is important to wean patients from the ventilator as soon as possible to reduce complications. Although the second article states that in the study it was observed that 22.4% of the patients who participated in the study had a delay of five or more days in starting the weaning process. According to this article, sedation management is a big factor in weaning because a higher sedated patient is directly related to a higher chance of weaning and extubation failure. The less sedated the patient is, the more improvement in the results of the weaning process will be seen and therefore a decrease in the percentage of extubation failures and avoiding complications such as reintubation or tracheostomy.

The Paulo A.F. et al. (2018) article (27) introduces Inspiratory muscle training. Although it is an option that is still being investigated, it is a good method to use in case the patient does not respond to the weaning process positively. This coincides with the fact that the use of VMI, according to the 6th article, produces diaphragmatic dysfunction, which indicates that after using VMI for a long time, it causes the diaphragm to lose its muscular strength. The results of these studies indicated a correlation between the improvement of inspiratory capacity and respiratory muscle strength. Moreover, both agree that this could be an action that helps improve the success of extubation.

The Onrubia X, Roca de Togores A. (2023) article (28)**,** confirms that the patient who had a difficult intubation will probably have a difficult extubation. Among the cases of extubation failure, it was observed that 26% of patients presented laryngeal oedema.

According to the Riddhi Kundu, et al. (2022) study (29)**,** the parameters that should be considered are pulmonary and cardiac function. Because of the main objective, this study aims to identify the alteration of these parameters by using ultrasonography.

In the study, a physician scans the thorax, before and after the SBT, and measures the lung ultrasound score (LUS) and the diaphragm thickening fraction

(DTF). The study concluded that a high LUS will likely lead to respiratory distress and a DTF lower than 26% is a predictor of weaning failure. Moreover, SBT was associated with loss of lung aeration. Even though the use of this technique is important, extubation should not be solely based on this parameter. If alterations are found, the patient can receive inspiratory muscle training.

Before extubating, the patient's inspiratory strength has to be evaluated using the Truwin and Marini test. Also, the strength of the muscles that interact in breathing, the respiratory system's impedance, and the volume inhaled each minute must be checked. The Shallow breathing index (SVR) or Yang and Tobin index, calculates the probability of the extubation to be successful. A rate greater than 106 breaths per minute indicates a high probability of extubation failure. On the other hand, a rate of less than 60 breaths per minute indicates a high probability of success in extubation. Extubation success is considered in any patient who is without intubation for 7 days or who was discharged from the intensive care unit without IMV (25).

To follow up with the extubation after a good weaning process the patient shall not present a loss of consciousness, there has to be a present cough and hoop reflex, the cardiovascular system does not depend on dopamine levels higher than 5 micrograms/kg/min and the EKG reflects a constant rhythm that is not classified as an arrhythmia or an ischemia. The heart rate is lower than 120 bpm, the RR is lower than 35 breaths per minute, the RSB is lower than 100 breaths/min/L and there is a presence of leak in the leak test. Patients who meet these criteria shall be extubated (26).

Also, a parameter that must be reviewed is the presence of oedema in the laryngeal area, as this is a major indicator of extubation failure. For this reason, corticosteroids, such as dexamethasone, hydrocortisone, or methylprednisolone, should be administered 12 to 24 hours after extubation, as a preventive measure. Another measure would be to observe with a laryngoscopy or video laryngoscope if the larynx is inflamed (28).

Moreover, the presence of a higher diaphragm thickening fraction (DTF) and lower lung ultrasound score, are important to measure to extubate successfully a patient. The study recommends that these parameters should be checked in the weaning phase before an extubation is made (29).

After the reading and the review of the literature that was found, the main and most recurred point stated in the articles was that more research on this field should be done to arrive at a consensus weaning protocol to identify the right time to extubate a patient (23,25–31).

6.1. LIMITATIONS OF THE STUDY

A principal limitation in this bibliographical review is that some articles may be identified with the research objectives and not have been reviewed. Moreover, the weaning process is related to a patient being admitted into the ICU, which means it is a very controlled patient. All of the procedures made to a patient are very suited to the context of the pathology of the patient and its state. It is very difficult to standardize a procedure that can change depending on the pathology of the patient. Finally, another limitation that should be considered is the lack of exhaustive investigation resources related to the role of the nurse in the weaning procedure.

7. CONCLUSIONS

After analysing and discussing the results, the conclusions are as follows.

- Weaning is a process that needs to be gradually followed with a standardized protocol that addresses each part of the patient's condition. The literature recommends that a standardized protocol should be followed during the extubation process, considering the criteria of each professional from the interdisciplinary team and the condition and pathologies of the patient. As the weaning process is strongly related to the IMV outcome, findings suggest that more research should be done in this field to create a standardized protocol, as there is not enough data to create a protocol. Especially because the IMV outcomes would be greater, and the extubation failures and mortality rates would decrease.

- It is recommended to do a spontaneous breathing trial to avoid the risk of extubation failure. However, it is emphasized that it should not be the only factor when considering extubation. It is one of the main factors, but not the only one, moreover, other items will identify that the patient is not ready to be extubated. Because of it is consequences, authors agree on the fact that IMV has to be removed as early as it can be.

- While doing the bibliographic review, a line of research was identified that is related to extubation failure and how to avoid it. It was not addressed as it was outside the scope of this research. Moreover, as the use of a T-piece, versus the use of pressure-support ventilation for spontaneous breathing trials is a discussion that was mentioned in the previous point, it was observed that it could be a further line of research.

8. CONTRIBUTIONS TO THE NURSING PRACTICE

According to the literature, the nursing role in the ICU is important for the patient. It was reported by the Acute Physiology and Chronic Health Evaluation (APACHE) score II, that the mortality rate was lower in ICUs that had a lower patient and nurse ratio. The mortality rate decreased when the ratio went from 5:1 to 2:1 (1.8% lower) (13).

As it is expected, the nurse follows a care plan, and it is provided continuously to be able to maintain the stability of the patient. Because of that, nurses maintain an important role in the care of the patient. Even though physicians hold an important role in the extubation process, it is considered that nurses are more likely to lead decisions that are related to the weaning process and the identification of the weaning failure. Taking into account that the process of weaning and the extubation of IMV are important and related, it is concluded that the final decisions about the extubation have to be made with the collaboration of the interdisciplinary team (32).

It is because of this that I consider the following bibliographic research to be an important topic to know about when a nurse is working in the ICU, as the nurse's view is also important for the final decision-making.

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