ПРЕДКЛИНИЧНА ВЕНТИЛАЦИЯ СЛЕД УДАВЯНЕ

Винсент Стайнберг[1], Жанина Ренер[1], Мария Пантелеева[2]

[1]Студент, Факултет по медицина, Медицински университет – Варна
[2]Катедра „Медицина на бедствените ситуации и морска медицина“, Факултет по обществено здравеопазване, Медицински университет – Варна

PRECLINICAL VENTILATION AFTER DROWNING

Vincent Steinberg[1], Janina Renner[1], Maria Panteleeva[2]

[1]Student, Faculty of Medicine, Medical University of Varna
[2]Department of Disaster Medicine and Maritime Medicine, Faculty of Public Health, Medical University of Varna

РЕЗЮМЕ

Удавянето е третата водеща причина за смърт при злополука с увреждане на дихателния апарат, изисква бърза реакция и правилно възстановяване на нормалния цикъл на дишане, за да се получи възможно най-добрият изход за спасените пациенти.

Освен дефиницията на самото удавяне и по-сложните поддефиниции на потопяване, потъване и нефатално удавяне това проучване се занимава с лечението намясто, както и с различните форми и режими на вентилация в доболничната среда. Показана е взаимовръзка между световната статистика на годишните жертви от удавяне, съставляващи около 7% от смъртните случаи от наранявания, от 236 хиляди починали от удавяне, или последиците му и множеството рискови и географски фактори. Тези данни не дават крайния брой смъртни случаи от удавяне, тъй като някои са изключени. Няма как да се получи напълно обективен и всеобхватен преглед на ситуацията в световен мащаб, тъй като точните измервания не са възможни.

Следователно приблизителният брой на жертвите на удавяне е много по-висок от статистическите данни. Затова правилното лечение и помощ, предоставени от минувачи или от обучени спасители, е от решаващо значение и влияе силно върху изхода от инцидента, който да бъде възможно най-добър и поддържащ живота в дългосрочен план.

Като се имат предвид множеството статистически данни, подобрението, постигнато от използването на ендотрахеална интубация и механична вентилация, е в състояние да све-

ABSTRACT

Drowning, being the third leading cause of unintentional accidents leading to death and mainly damaging the respiratory apparatus, demands a quick response and the correct reestablishment of a normal breathing cycle in order to obtain the best possible outcome for rescued patients.

Besides the definition of drowning itself and the more complex sub-definitions of submersion, immersion, and non-fatal drowning, this study deals with the onsite treatment as well as the different forms and modes of ventilation in the prehospital setting. It explores the correlation between global drowning statistics, which account for approximately 7% of injury deaths annually with 236 thousand fatalities directly related to drowning or its consequences, and the multiple risk factors and geographical circumstances involved. However, this just implies the total extent of deaths caused by drowning since certain cases remain excluded. It's nearly impossible to gain a completely objective and overarching overview of the worldwide situation since exact measurements are not possible.

Therefore, the estimated number of drowning victims is much higher than statistics show. Correct treatment and aid provided by bystanders or professional first-aiders are important and highly impact the outcome of a drowning accident, which should be as protective and life-sustaining as possible in the long term.

According to multiple statistics, the improvement due to endotracheal intubation and mechanical ventilation is capable of minimizing inadequate ventilation by less effective forms of manual ventilation—mouth to mouth, mouth to nose without equipment, with bag valve masks (BVM), or supraglottic airway management—which might even lead to injuries restraining the patient´s rehabilitation.

де до минимум неадекватната вентилация чрез по-малко ефективни форми на ръчна вентилация - уста в уста, уста в нос, без оборудване, с АМБУ или устройства за супраглотичните дихателни пътища, които могат да причинят травми, възпрепятстващи рехабилитацията на пациента.

Ключови думи: *механична вентилация, първа помощ, удавяне, управление на дихателните пътища, доболнично*

Keywords: *mechanical ventilation, first aid, drowning, airway management, prehospital*

INTRODUCTION

Drowning is a common incident that occurs near bodies of water or any liquid source. It causes a significantly higher number of deaths compared to malnutrition or malaria. Unfortunately, the risk of drowning is often underestimated, resulting in the loss of many lives. While it is possible to prevent some drowning cases, not all can be avoided. Factors like climate change contribute to the increased occurrence of extreme weather events such as floods, further raising the risk of drowning for many individuals. These factors are challenging to address directly. Therefore, the provision of first aid measures, including proper ventilation following a drowning incident, is equally important alongside prevention efforts. This article aims to examine and evaluate the various methods of preclinical ventilation, considering their effectiveness.

Drowning ranks as the third leading cause of unintentional injury deaths globally, according to the World Health Organization (WHO). In 2019 alone, it accounted for approximately 236,000 deaths, representing around 7% of all injury-related fatalities. The majority of deaths due to drowning occur in lower or middle-income countries, with more than 90% of the cases reported in these regions. Certain demographics face a higher risk, including young children, males, and individuals with greater exposure to bodies of water. Other risk factors include low socioeconomic status, a lack of education, alcohol, diseases like epilepsy, and many more (18).

According to a 2017 statistic on accidental drowning or submersion deaths in European countries, Bulgaria has an average of 1.7 deaths per 100,000 inhabitants. However, Latvia and Lithuania have the highest number of deaths, with values more than twice as high as those in Bulgaria. Despite this, Bulgaria still ranks 8th among the 27 countries listed (9). The relatively high number of drowning deaths in Bulgaria can be attributed to the widespread access to water along the Black Sea coast.

AIM

The aim of this research is to review the possibilities for airway management and different ways of ventilation in drowning casualties for first aid and for treatment.

MATERIALS AND METHODS

A comprehensive review of scientific articles, guidelines, and other relevant sources was conducted to assess the first aid measures administered by both lay bystanders and professional first aiders for drowning victims. A comparison was made between manual and mechanical ventilation methods to evaluate their impact on victim outcomes.

Definition of drowning

According to the WHO, drowning is defined as the process of experiencing respiratory impairment resulting from submersion or immersion in a liquid, with outcomes classified as death, morbidity, or no morbidity (18). As stated by the Emergency Care Institute (ECI), it can be further differentiated between submersion, immersion, and non-fatal drowning (8):

- Submersion describes the case in which the patient is completely covered by the liquid.
- Immersion refers to the case in which the patient is only partly covered by a liquid.
- Non-fatal drowning, sometimes still called near drowning, describes the case in which the patient survives for more than 24 hours after the drowning event.

It is important to note that most statistics referring to drowning deaths exclude intentional drowning as well as drowning due to flood disasters and incidents in water transport. This has to be taken into account when analyzing statistics since the given values are therefore not representative of all deaths caused by drowning according to the definition of the WHO. Including all possible reasons for drowning, the number of deaths due to drowning can increase by up to 50% in some countries. Additionally, data about non-fatal drowning in most countries does not exist yet or is not reliable (18).

How to decide whether ventilation or CPR should be used

Different circumstances call for different first aid measures in cases of drowning. The two common ways are cardiopulmonary resuscitation (CPR) and ventilation in the form of mouth-to-mouth resuscitation, also called artificial respiration or rescue breathing. In any case, CPR or ventilation should be provided as soon as possible since damage to the patient increases with time. If the pulse of the patient is still detectable, ventilation is sufficient, and no CPR should be given. In cases where no pulse is detectable, CPR and ventilation should both be provided.

Manual ventilation

Ventilation is the process of exchanging air between the lungs and the atmosphere in order to allow an exchange of oxygen and carbon dioxide in the alveoli. Two main methods of ventilation exist: manual ventilation and mechanical ventilation. Manual ventilation does not require the use of a medical device and can be performed by hand. Ensuring a continuous exchange of oxygen and carbon dioxide is crucial for maintaining the body‘s essential functions. In cases where a patient is not breathing, ventilation has to be provided either mechanically or manually. There are different variations of manual ventilation.

During mouth-to-mouth ventilation, the patient has to be positioned in a stable side position with the neck overstretched to keep the airways free. The patient‘s nose should be closed. Then the person who gives first aid has to breathe carefully into the patient‘s open mouth. Excessive pressure during ventilation can result in air entering the stomach, potentially triggering vomiting in the patient. This should be avoided to ensure patient comfort and safety (6).

In the case of mouth-to-nose ventilation, the same procedure is carried out, but in this case by closing the mouth and breathing into the nose. The risk of patient vomiting is reduced during mouth-to-nose ventilation (7).

The bag valve mask (BVM) can be used as a third alternative option. It is important to select the appropriate mask size based on the patient‘s facial dimensions. The mask should cover both the mouth and nose tightly so that the air that will be pumped into it cannot escape. An oxygen-filled bag is attached to the mask. The bag has to be squeezed in a manner that mimics the natural inhalation rhythm during the breathing cycle (3).

In all three cases, ventilation has to be carried out until the patient starts to breathe again. Monitoring the natural rise and fall of the chest can serve as an indicator of the patient‘s resumption of breathing.

PROFESSIONAL FIRST AID AND EMERGENCY RESCUE

Airway management material in professional emergency rescue

This section focuses on the mechanical aspect of ventilation and the equipment required in emergency rescue. Examples of materials and ventilators currently used will be provided. It‘s important to note that the choice of materials can vary significantly depending on the organization and country, as there are no specific or mandatory guidelines for their provision.

Generally, it can be stated that mechanical ventilation provides far more controlled and constant ventilation than manual ventilation and therefore provides better outcomes for patients treated by professional emergency rescue teams. Along with airway protection materials such as endotracheal tubes, extraglottic or laryngeal tubes, masks, laryngoscopes, and oxygen, ambulances are increasingly equipped with ventilators from various manufacturers, each using different approaches.

According to a study by the Scandinavian Journal of Trauma, Resuscitation, and Emergency Medicine, the most commonly used ventilator is the Oxylog 3000-series by Dräger Lübeck, based in Germany. This ventilator offers volume and pressure-controlled ventilation, with mandatory and assisting ventilation modes (10,17,19).

Taught procedures in emergency rescue

Currently used literature in German paramedic training gives clear guidelines about how to treat a submerged or immersed patient who has lost consciousness, which this article mainly focuses on. The guidelines primarily refer to international recommendations from the American Heart Society, suggesting a slightly modified approach for resuscitating patients who have been submerged in either saltwater or freshwater. There is no further differentiation regarding the specific causes of unconsciousness or acute respiratory distress syndrome („ARDS“) (11).

In addition to the obligatory extended monitoring, which includes repeated blood pressure measurements, pulse oximetry, ECG, blood sugar, and temperature control, an off-standard procedure is recommended. After the initial five ventilations before initiating chest compressions, the importance of performing them correctly is emphasized. Due to the potentially large amount of water swallowed in the drowning process, chest compressions should have as little impact on the stomach as possible to prevent aspiration of water or other fluids in the early phase of reanimation. To further prevent aspiration, the permanent use of a ready-to-use suction pump is recommended, as is the early use of a gastric tube. This can also take pressure off the lungs due to the large amount of liquid in the stomach (11).

In most cases, endotracheal intubation is considered the safest choice in emergency rescue, considering the risk of aspiration and the high level of pressure occurring during the ventilation process. The circumstances in the field of emergency medicine often require the application of rapid sequence induction, often referred to as crash-intubation. This technique is described as a method of airway management that rapidly induces unresponsiveness through the use of an induction agent and neuromuscular blocking agent, providing the fastest and most effective means of controlling the emergency airway (9).

Furthermore, a positive end-expiratory pressure (PEEP) of 5–10 mbar, gradable up to 20 mbar (depending on the effectiveness of the ventilation, considering an adequate tidal volume being calculated with 6 ml/kg ideal body weight), is recommended. The aim is to be able to gain blood oxygenation levels between 94 and 98% with a FiO2 of 100%, as in nearly all life-threatening situations. The aspired level of expiratory CO2 is between 35 and 45 mmHg, or 5% of the total exhaled air volume (11).

Decision-making in emergency rescue: „Stay and play" or „Load and go"

The situations faced by rescuers and healthcare providers when making decisions regarding the treatment of individuals who have experienced life-threatening accidents are often complex and difficult to standardize. However, certain criteria play a significant role in guiding these decisions. In some cases, it may be crucial to prioritize keeping the patient alive, but it is essential to consider the potential risks of performing additional therapies or time-consuming procedures without certainty regarding the patient‘s condition.

There are several key factors that significantly influence decision-making, and they can be broadly categorized as follows: geography, logistics, individual skill sets, and available resources. These factors play a critical role in determining the course of action in various situations (14).

A study conducted in 2016 revealed that approximately 5.3% of the patients included in the research required advanced airway management. However, it was observed that the percentage of patients undergoing invasive treatments had decreased in subsequent cases. This indicates that only a small proportion of emergency situations handled by professionals necessitated complex and invasive procedures prior to hospital transportation (14).

The same study also provides valuable insights into the number and success rate of endotracheal intubations performed and whether they were successful or not. This information allows a deeper understanding of the associated risks involved in the decision to proceed with this type of airway management. The statistics indicate that only 3.4% of all intubations conducted by emergency doctors were deemed unsuccessful (14).

Furthermore, a study of the CARES (Cardiac Arrest Registry to Enhance Survival) database published in the National Library of Medicine states that patients who were intubated with an endotracheal tube had significantly higher odds of survival than those who received supraglottic airways (SGA). (12)

Another study shows that in 57.1% of the cases in which a laryngeal tube was used, the ventilation provided was insufficient (2).

These findings highlight that, in the majority of cases, under favorable conditions, endotracheal intubation remains the most effective method for safeguarding the airways of patients who have experienced injuries or incidents necessitating advanced airway management, including drowning accidents.

Favorable situations for usage of mechanical ventilation

The National Association of EMS Physicians (NAEMSP) recommends the use of mechanical ventilation in prehospital settings where any form of ventilation is required. This recommendation is based on the advantages offered by mechanical ventilation, such as precise monitoring capabilities, which help prevent ventilator-associated lung injuries during rescue and transport. By ensuring a consistent respiratory rate and tidal volume, maximizing ventilation, improving oxygenation, and minimizing complications like barotrauma, pressure, and flow-related issues, mechanical ventilation provides a safer and more controlled approach. Additionally, it allows paramedics, EMTs, and doctors to allocate their resources effectively, focusing on other aspects of patient care (1).

When it comes to mechanical ventilation, there are various modes available, each suited for specific circumstances to achieve optimal ventilation and oxygenation for the patient. These modes can be categorized as either invasive or non-invasive, and they can further be classified as volume-controlled or pressure-controlled ventilation.

Invasive ventilation is generally performed on patients who are unable to carry out adequate gas exchange independently or are at risk of losing their ability to breathe spontaneously. This can be due to factors such as loss of consciousness and, therefore, a lack of airway protection. The following section, different modes of invasive ventilation will be presented.

Assist control (AC)

Assist Control (AC) is a widely used ventilation mode in various clinical settings. In AC, a target is set, which can be a specific tidal volume (TV) or peak inspiratory pressure, along with positive end-expiratory pressure (PEEP) and the respiratory rate. When the patient fails to initiate a spontaneous breath, the ventilator is triggered and performs a complete respiratory cycle until the set target is reached. If the patient takes a breath independently, the ventilator either remains inactive or temporarily pauses the mechanical ventilation.

AC mode finds application on different occasions. Its simplicity makes it particularly suitable for emergency situations where obtaining a comprehensive overview can be challenging. The volume-controlled variant is commonly employed to assist patients in respiratory distress and provide sufficient air to the lungs during accidents or emergencies.

Its pressure-controlled variant, whose biggest advantage is to prevent barotrauma, is often used in situations when the patient is at high risk of alveolar damage or failure (4,16).

Synchronized intermittent mandatory ventilation (SIMV)

SIMV is a ventilation mode that combines components of assist control and pressure support (PS). Typically, a low respiratory rate (RR) is set, usually around 8–10 breaths per minute. Various parameters need to be configured, including volume or pressure, RR, flow, or inspiratory time. The ventilator delivers the pre-set breaths, but if the patient initiates additional breaths in between, the ventilator provides support with pressure to ensure optimal oxygenation and gas exchange. SIMV can be employed in both weaning and emergency situations where the patient still exhibits some spontaneous breathing. It allows for a synchronized approach to support the patient‘s independent breaths while ensuring adequate ventilation and oxygenation (4,16.)

Pressure support (PS)

The ventilation mode known as pressure support (PS) is designed to alleviate the workload for patients who are breathing spontaneously. In this mode, a baseline pressure known as positive end-expiratory pressure (PEEP) is applied to prevent the collapse of unstable alveoli. Additionally, a breath-triggered support pressure is provided to counteract the resistance in the airways. Furthermore, PS senses the flow of the patient‘s breaths and discontinues the support pressure when the flow decreases below a certain threshold, allowing the patient greater control over their breathing pattern.

Due to its nature of providing partial support, PS is primarily utilized in weaning situations where patients are transitioning towards independent breathing. This mode helps patients manage their respiratory effort while still receiving necessary assistance (4,16).

Pressure regulated volume control (PRVC)

This ventilation mode combines elements of both volume- and pressure-targeted ventilation. As a subform of AC, it operates primarily in a volume-controlled manner with a predetermined tidal volume (TV). However, it also incorporates the ability to deliver the TV at the lowest feasible peak inspiratory pressure (PIP) to minimize the risk of barotrauma, a form of injury caused by excessive pressure. The PIP is set by medical personnel, and when it reaches this level, the ventilator promptly transitions to the expiration phase. An alarm is triggered to alert clinicians, allowing them to adjust the settings and ensure optimal ventilation without causing harm to the alveoli or other parts of the respiratory system. This ventilation mode is highly lung-protective and adaptable to changes in the patient‘s breathing pattern, effectively preventing both volutrauma and barotrauma (16).

Alternatively, if the patient is partially conscious and the risk of aspiration or airway obstruction is minimal, noninvasive ventilation or noninvasive respiratory support is employed.

Noninvasive positive pressure ventilation (NIPPV)

Noninvasive positive pressure ventilation (NIPPV) is commonly used in patients with respiratory failure. Instead of employing an invasive endotracheal tube, a well-fitting mask is utilized, covering the patient‘s nose and mouth. This form of ventilation is further categorized into two subforms. To be eligible for NIPPV, patients must have adequate airway protection (16).

Continuous positive pressure ventilation (CPAP) provides the receiving patient with a pressure similar to the PEEP in invasive ventilation, which also protects the alveoli from collapsing and decreases the amount of work to be done during a respiratory cycle. It is mostly used in the treatment of conscious patients with hypoxemic respiratory failure and those requiring assistance with alveolar recruitment (16).

The **bi-level positive airway pressure (BPAP or BiPAP),** on the other hand, provides two different levels of pressure. The higher inspiratory peak airway pressure (IPAP) is analogous to the IPIP in invasive ventilation, and the lower expiratory peak airway pressure (EPAP) is comparable to the pressure provided in CPAP or PEEP. By using those two levels of pressure support, this ventilation mode is very useful for patients who suffer from COPD or other illnesses that cause poor ventilation and hypercapnic respiratory failure (16).

Further treatment approaches

After rescuing a drowning patient and ensuring they do not experience cardiorespiratory arrest, the next step is to provide respiratory support using one of the previously mentioned ventilation options. However, it is crucial that further treatment takes place in a specialized hospital environment to ensure the best possible outcome for the patient.

During this challenging treatment, the primary goal is to ensure adequate ventilation and promote effective healing of the potentially damaged lungs. Achieving sufficient respiration is essential to preventing dyspnea and maintaining oxygenation levels above 95% SpO2 without compromising the patient‘s respiratory effort. A retrospective prospective study, published in an article in the National Library of Medicine, reported that out of 17 near-drowning cases, all patients had pulmonary edema. Among the surviving patients, 82.4% received prophylactic antibiotics to prevent pneumonia, which is a high risk in individuals who have experienced drowning accidents. Additionally, 47% of the patients required mechanical ventilation, highlighting the undeniable importance of mechanical ventilation in the ongoing treatment process (13).

Optimal results, achieved through different ventilations

A comprehensive article about mechanical ventilation in the prehospital and emergency department environment reviewed data that showed early application of lung protective ventilation having a severely positive impact on the outcome for patients with multiple lung injuries or diseases, including ARDS. The article emphasized the association of poor outcomes with prehospital hyperventilation and hypocapnia, which are more likely to occur with non-protective and manually performed ventilation. To address these concerns, the article recommended the use of ventilators operated by trained personnel who can continuously monitor and adjust the ventilation settings as needed. Recent studies furthermore highlighted that only 27.1% of the ventilated patients were ventilated protectively, which the article describes as being achieved by combing low tidal volumes with stepwise titration of FiO2 and PEEP to obtain adequate oxygenation without risking ventilator-associated injuries.

The LOV-ED trial (lung-protective ventilation initiated in the emergency department) aimed to improve the quality of care for mechanically ventilated patients. The trial recommended an initial tidal volume (VT) of 6–8 ml/kg predicted body weight (PBW) and a starting FiO2 of 30–40% to avoid hyperoxia, with the possibility of adjustments in combination with PEEP as needed. However, the article acknowledges the complexity of individual cases and the need for tailored treatment approaches. The effectiveness of early implementation of lung protective ventilation was evident in the LOV-ED intervention, which resulted in a reduction in mortality rates from 14% to 17.5% in emergency departments (15).

CONCLUSION

The frequency of drowning accidents highlights the need for immediate professional intervention in the form of ventilation to maximize the chances of a positive outcome for the patient. However, it is crucial to have a thorough understanding of the different ventilation modes and their appropriate application to avoid errors that could negatively impact the patient‘s condition. While preclinical ventilation administered on-site is of the utmost importance, it also carries risks if not performed correctly. Therefore, comprehensive knowledge and proficiency are essential, particularly in manual ventilation, where there is no assistance or control system provided by a machine.

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Адрес за кореспонденция:
Scientific supervisor:
Prof. Maria Panteleeva-Popova, MD, PhD
Department of Disaster Medicine and Maritime Medicine, Faculty of Public Health
Medical University of Varna
55 Marin Drinov St.
Varna, 9000
e-mail: maria.panteleeva@mu-varna.bg
Phone number: +359 52 677 190