A Survey of ventilation techniques for the treatment of ARDS

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ABSTRACT

Acute Respiratory Distress Syndrome (ARDS) is a horrendous disease that affects around 30 lakh people per year. People having bronchitis and those who have been prone to Covid-19 have more chances of acquiring it. Ventilation is the best choice for treatment of this dreaded disease for patients who are suffering severely from it and are admitted into the ICU. Unfortunately, ventilators that are presently being used have their own pros and cons. They are very costly with high maintenance cost. This paper presents a survey of the various ventilators that are used for the treatment of ARDS and proposes a new ventilating system to subdue the demerits that are there in the existing ones. The proposed ventilating system is going to be evaluated based on performance metrics such as accuracy, precision, and sensitivity.

Keyword: - *ARDS, diagnostic, lungs, dysfunction, symptoms*

1. INTRODUCTION

Acute Respiratory Distress Syndrome (ARDS) is a type of panting misstep delineated by expeditious onslaught of all over the place swelling in the lungs [11]. The condition was first purported in 1967. ARDS affects more than 3 million people a year around the globe and has a fatality rate ranging between 35% and 50%.

1.1 Signs and Symptoms

Signs and symptoms may be due to cyanosis, tachypnea, dyspnea, hypoxemia due to improper ventilation, muscle fatigue, fever, low blood pressure, and dry hacking cough [12]. For those who survive, a sapped trit of life is prevalent. Fig-1 [1] depicts the normal alveolus and the injured alveolus during the acute phase of ARDS.

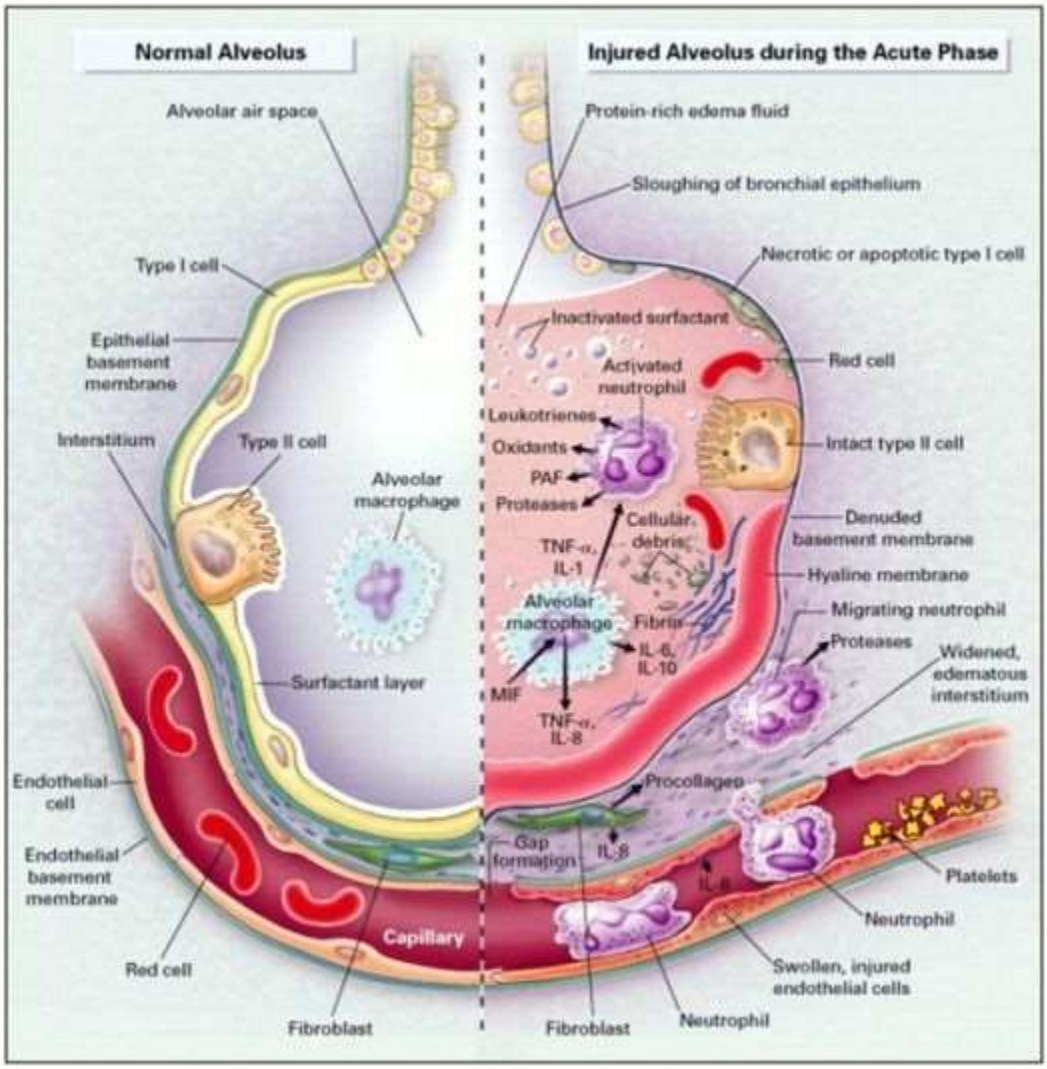

Fig-1 Normal Alveolus and the Injured Alveolus during the acute phase of ARDS [1].

1.2 Causes

The causes of ARDS are mainly due to Covid-19, pneumonia, aspiration, pancreatitis, trauma, etc. The ARDS debilitates the lungs' competence to quid pro quo oxygen and carbon dioxide [11]. Medical scrutiny is based on a ratio of partial pressure arterial oxygen and fraction of inspired oxygen of lower than 300 mm Hg regardless of a positive end-expiratory pressure (PEEP) of aggrandizement than 5 cm water.

1.3 Treatment

The primary treatment makes use of mechanical ventilation in combination with other treatments based upon the actual cause and occurrence of the disease. Ventilation strategies include using smaller volumes and lesser squeezes [11]. If oxygenation is incommensurate, extracorporeal membrane oxygenation (ECMO), lung recruitment maneuvers and neuromuscular blockers are preferred.

Patients affected by ARDS are usually admitted into the Intensive Care Unit (ICU) where they are provided with mechanical ventilation. This is done by providing a intransigent tube which enters the mouth and is given into the airway by a procedure called endotracheal intubation, or by another method known as tracheostomy when ventilation is required for longer durations of time [11]. The mission of mechanical ventilation is to preserve

admissible gas swap to meet the body's metabolic requisitions and to reduce inimical effects in its use. The parameters mean airway PEEP, and plateau pressure are used [12].

1.4 Complications

Complications of using ventilators may be as follows [13, 14]: -

- Kidney: acute kidney failure, positive fluid balance.
- Neurological: hypoxic brain damage.
- Lungs: pulmonary fibrosis, volutrauma, Ventilator-Associated Pneumonia (VAP).
- Gastrointestinal: bacterial translocation.
- Cardiac: myocardial dysfunction.
- Mechanical: pneumothorax.
- Nutritional: electrolyte abnormalities.
- Complications that arise from treatment in a hospital including blood clots, muscles' weakness.
- Depression.
- Pulmonary hypertension.
- Multiple organ failure leading to death.

2. RADIOLOGICAL IMAGING

Radiologic imaging has long been a criterion for diagnosis of ARDS. For the earlier detection of ARDS, Correlative Chest X-Ray findings were required for diagnosis; but now the diagnostic criteria have been expanded to include Computed Tomography (CT) and Ultrasound Imaging findings as being more information bearing means. Generally, radiographic findings of fluid accumulation (pulmonary edema) affecting both lungs and unrelated to increased cardiopulmonary vascular pressure may be suggestive of ARDS.[17] Ultrasound findings suggestive of ARDS include information such as Anterior subpleural consolidations, Absence or reduction of lung sliding, Spared areas of normal parenchyma, Pleural line abnormalities and Nonhomogeneous distribution of B-lines [14].

Based upon the above paragraph, it is intuitive to infer that the field of Electronics and Communication (ECE) Engineering plays a pivotal role in the detection of ARDS and also aids the doctor in the kind of treatment that needs to be meted to the patient. This paper gives a survey of some of the methods that have been used in ARDS detection and also highlights the merits and pitfalls of these methods. A new system that eliminates the problems present in the current methods and which eliminates them is proposed at the end [14].

3. LITERATURE SURVEY

T. Owodolu et al [2] describe the development of portable mechanical ventilator using a proportional solenoid valve whose aim is to regulate the flow rate of oxygen to the patient together with the Arduino Mega 2560 as the main controller for the machine before delivering the required volume to the patient; based on their ideal body weight so as to prevent blowing out the lungs. The aim of this particular work is to save and improve the quality of lives of patients with respiratory problems rather than replacing the existing ventilator. Furthermore, test analysis was conducted to evaluate its performance and also the comparative analysis between the standard and the developed ventilator showed the reasons why most hospitals did not have ventilators.

The paper by Subha Hency Jose P [3] deals with the hardware design of a lab model ventilator for ARDS treatment. A prototype model of the ventilator was designed and tested by the authors to assist the patients who can partially breathe by their own. This device is provided with very basic design and reliable structure that is easily acceptable by the patient. Main focus in this paper is to minimize the components and increase the efficiency of the device, so that while using this device to the patient, they should feel as comfortable as the normal ventilator. Needle valve is used along with the potentiometer for replacing the flow analyzer so that the entire setup is cost effective. Arduino UNO board is used because it is easy to program. This work led to the development of lab model ventilator.

T. Muthumanickam et al [4] propose a new approach called intelligent ventilation that allows regulating fans and even heat distribution, depending on the parameter that the designer deems appropriate for specific areas. This parameter is read by a probe or sensor, which transforms the parameter itself into a digital or electrical signal,

so that it can be read by a regulatory element that will tell the fan how to operate, while increasing the speed, reducing it or even turning it off.

The work of Asmaa I. Abd-Elsadek et al [5] is aimed towards increasing productivity of firms in Egypt by proposing an easy-to-use, easy-to-build and small size mechanical ventilator with a unique design, so as to prevent massive loss of life in resource-poor environments especially w.r.t ARDS. It proposes the Simulation of the Ventilation process with the help of MATLAB (Simulink) environment to observe results and prevent risks, the results show the different responses for different support modes proposed and the Alarm System is to declare any issues. Also, it contains the Mechanical Design, Circuit Schematic and Control Strategy needed to implement the simulation in reality.

Tamir Yeshurun et al [6] have developed a simulator of a medical ventilation including realistic, autonomously breathing lungs model. The simulator allows testing different control schemes for the ventilator and its synchronization with a breathing patient. Implementation of this model may assist in efforts to develop simple and accessible medical ventilators to meet the global demand.

Chuchart Pintavirooj et al [7] have developed a blower-based pressure-controlled ventilator for home-treatment of COVID-19 patients getting ARDS. One of the features of this ventilator is its designed flow and pressure sensor, electronic peep valve and proportional controlled valve. This ventilator can be programmed with the suitable parameter setting depending upon the weight, height, gender, and blood oxygen saturation of the patients. The designed ventilator is also equipped with a safety mechanism, including an excessive-pressure-release valve, excessive flow rate, overpressure, and over-temperature blower to prevent any hazardous event.

K. Rajan [8] has developed a ventilator whose control unit receives the signal from the key switch at the time of turning on the ventilator with the help of the weighing sensor. This was developed for ARDS patients' treatment. Once the patient is fitted with the ventilator, the load cell sensor sends the signal to the controller to perform the necessary functions. The controller drives the signal to the 5/2 way solenoid valve which actuates the double-acting cylinder for proper functioning of the ventilator.

4. PROPOSED SYSTEM

The literature survey of the previous section shows the lack of performance metrics in assessing the performance of the various ventilators' functionalities w.r.t ARDS requirement. Also, there is a lack of extra interfacing features that are required in the real-time operation of a Ventilator. Another drawback is their high cost and maintenance.

We propose Virtual Reality (VR) Technology can be used to create an immersive training environment where healthcare professionals can practice diagnosing and treating ARDS cases in a safe and controlled environment. This technology can help in incrementing the engagement and retention of knowledge. Mobile applications can be a great useful tool for healthcare professionals to access ARDS training material on the go. The proposed system aims to make use of Arduino Atmega 128 microcontroller with a 4 channel relay and 12 V, 5 A power supply, with a tank and compressor. We aim to give four valves. The performance of the proposed system is going to be evaluated based on various performance metrics such as accuracy, precision, and sensitivity. Providing VR Technology and having mobile applications interfaced to it increases the accuracy and speed which is the hallmark of the proposed system. Also, the hardware required for our proposed system is very less as Arduino processors are very cheaply available in the market. Thus, we can have cheap and best operating ventilators with minimum maintenance requirement. This system also mitigates the side effects in the patient's body when they are put on ventilators.

5. CONCLUSION

Human life is very precious. Saving life of people using ventilators is very expensive and intricate. Ventilators are the heart and soul of saving patients when they are admitted into the Intensive Care Unit (ICU). But they are exorbitant in nature. Hence, research into development of cheaper ventilators that are cost effective but whose performance is worthwhile is the order of the day. This paper gives a literature survey of various ventilators

that have been developed for ARDS treatment and also highlights their pitfalls. An alternative ventilator system is proposed which is cost-effective, consumes less power, and takes less hardware and software requirements. Finally, the proposed system is going to be guesstimated based on various performance metrics which is a major benchmark in deciding about the assiduity of any system and also overcomes the sideffects in the patients when they are put on ventilators.

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