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Shwaas: A Low-Cost Ventilator for Resource-Constrained Environments

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ABSTRACT

This research paper presents the design and development of a low-cost ventilator, named "Shwaas". The aim of the project was to address the rising need for affordable and accessible ventilators, particularly in resource-constrained environments and rural hospitals. The ventilator was developed using readily available components, including a bag valve mask, an Arduino Nano microcontroller, a stepper motor, and an LCD display. The system provides real-time information on the tidal volume and pressure, allowing for effective ventilation management. The challenges faced during the development process, including limited resources and time constraints, are discussed. The Shwaas ventilator has the potential to significantly impact respiratory care in resource-constrained environments and provide life-saving support to those in need.

Keywords— Low-cost ventilator, Shwaas, resource-constrained environments, rural hospitals, bag valve mask, Arduino Nano, stepper motor, LCD display, tidal volume, pressure, respiratory care, ventilation management, life-saving support.

Introduction

Ventilators are medical devices that help people who are unable to breathe on their own. They are an essential tool in critical care medicine and have a rich history dating back to the 19th century. In this section, we will explore the history of ventilators and their evolution over time.

The first mechanical ventilator, called the Iron Lung, was invented in 1928 by an American inventor named Philip Drinker. The Iron Lung was designed to help patients with polio who were unable to breathe on their own. The machine worked by creating a negative pressure inside a chamber that the patient was placed in, which allowed air to be drawn into their lungs. The Iron Lung was a large, cumbersome machine, but it proved to be a life-saving invention, particularly during the polio epidemics of the 1940s and 1950s.

Iron Lung

Credit – University of Rochester

In the decades that followed, ventilator technology continued to evolve. In the 1950s, positive pressure ventilation was introduced, allowing for greater control over the amount of air delivered to the patient's lungs. This breakthrough made mechanical ventilation more effective and reliable. Over time, smaller and more portable ventilators were developed, making critical care more accessible in a variety of settings.

In the 1970s, ventilators were first introduced in India. These machines quickly became an essential tool in critical care medicine, particularly in urban centers. However, despite their widespread use, the high cost of ventilators remained a significant barrier to providing care to patients in rural hospitals and low-resource environments.

BACKGROUND

Respiratory failure is a life-threatening condition that can occur due to a variety of factors, such as chronic obstructive pulmonary disease (COPD), pneumonia, and acute respiratory distress syndrome (ARDS). In cases where a patient's lungs are unable to function properly, mechanical ventilation is often necessary to support their breathing and help oxygenate their blood.

With the rise of respiratory illnesses worldwide, particularly in the wake of the COVID-19 pandemic, the demand for ventilators has skyrocketed. Hospitals and healthcare systems around the world have struggled to keep up with the demand, leading to shortages in many parts of the world. This has highlighted the urgent need for more affordable and accessible ventilator technology, particularly in low-resource environments where critical care is often scarce.

In India, the need for affordable ventilators has been particularly acute. The country has seen a rapid increase in respiratory illnesses in recent years, with COPD alone affecting an estimated 55 million people. Despite this high demand, ventilator technology has remained largely inaccessible to many patients in rural areas and low-resource environments, due to the high cost of these devices.

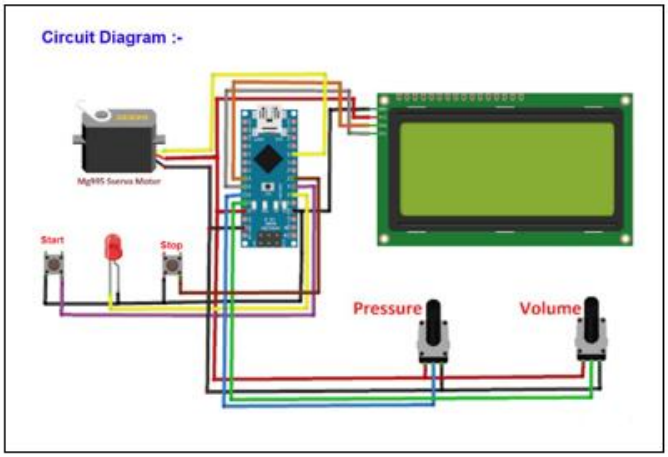
Design &DEVELOPMENT

We aimed to design and develop an affordable, easy-to-use ventilator that could be used in resource-limited settings. After conducting extensive research and analysis of existing ventilator designs, we settled on a design that relied on a bag valve mask, an Arduino Nano microcontroller, an LCD display, and a stepper motor.

The bag valve mask, a simple and widely available medical device, served as the basis of our ventilator design. We modified the bag valve mask by adding an attachment mechanism that allowed us to control the flow of air and oxygen to the patient. We then connected the bag valve mask to an Arduino Nano microcontroller, which served as the brains of the ventilator.

The Arduino Nano was programmed to control the speed and direction of a stepper motor, which was connected to the bag valve mask attachment mechanism. By rotating the stepper motor, we were able to control the flow of air and oxygen to the patient, as well as monitor the amount of pressure and tidal volume being delivered in real-time using an LCD display.Throughout the design and development process, we focused on ensuring that the Shwaas ventilator was easy to use, affordable, and could be quickly assembled using widely available components.

A) Circuit Design:

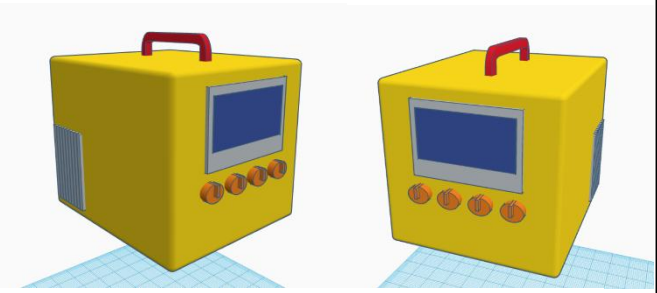


The circuit design of the Shwaas ventilator consists of two potentiometers for controlling the flow of pressure and volume. The pressure potentiometer controls the pressure within the system, and the volume potentiometer controls the tidal volume delivered to the patient. There are also two push

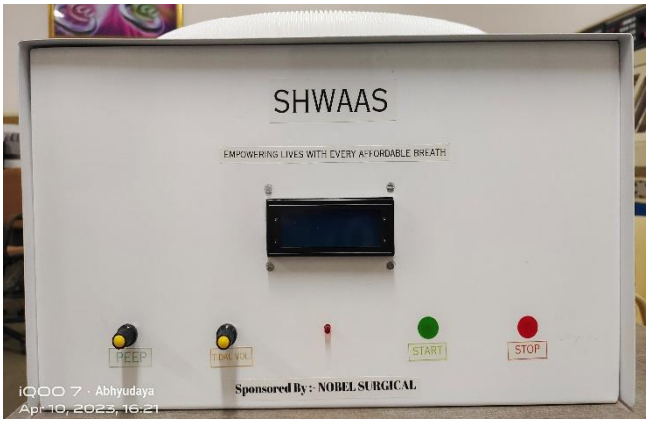
buttons, one for starting and the other for stopping the ventilator. The circuit is powered by a DC power supply.
The MG995 servo motor is used to control the actuation of the bag valve mask. The motor rotates in a clockwise and anti-clockwise direction to compress and release the bag valve mask, respectively. The 20x4 I2C LCD display is used to provide real-time information on the tidal volume and pressure generated by theventilator. The display is controlled by the Arduino Nano microcontroller, which also processes the signals from the potentiometers and push buttons.

B) Structural Design

The structural design of the ventilator consists of a mild steel sheet, which is cut and molded into the required dimensions. This sheet is then punched with louvres for better internal ventilation. Louvres are openings in the ventilator that help in the exchange of air between the ventilator and the environment. After the sheet is punched with louvres, it is coated with white glossy spray paint. This coating not only enhances the aesthetics of the ventilator but also protects it from rust and corrosion. The mild steel sheet is a popular choice for making the ventilator as it is strong, durable, and easy to mold into various shapes and sizes. The punched louvres help in the free flow of air, and the white glossy spray paint gives it a finished look.



3D images of the ventilator



The above image is of the actual ventilator made by the team

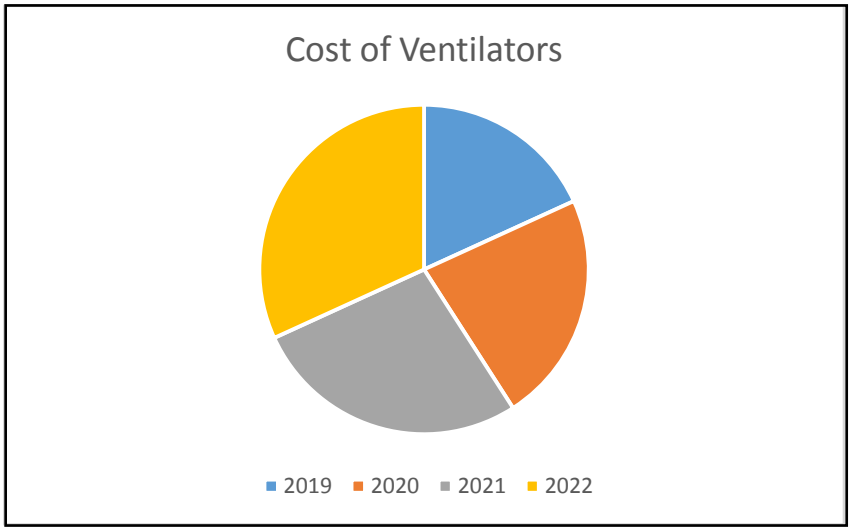
Below images are of the team while assembling and developing the Ventilator.




Challenges

The development of the Shwaas ventilator was not without its challenges. One of the main challenges faced by the team was the cost of the components. While the team was able to keep the cost low by using readily available and affordable components, the cost of the components still posed a significant challenge. This was because many resource-constrained environments and rural hospitals do not have the budget to purchase expensive medical equipment, including ventilators. Therefore, the team had to ensure that the cost of the ventilator was low enough to be affordable for these settings. Below is a pie chart which represents the increased cost of ventilators over last 4 years, starting from 2019 - 2022

Another challenge faced by the team was testing the ventilator. The team had limited resources& time and had to rely on simulations and tests using artificial lungs.



Conclusion

The Shwaas ventilator developed by the team of students from Thakur Polytechnic has the potential to address the rising need for affordable and accessible ventilators, particularly in resource-constrained environments and rural hospitals. The use of readily available and affordable components, coupled with the real-time monitoring of tidal volume and pressure, makes the ventilator an effective and reliable solution for respiratory support.

The success of this project serves as an example of how innovative and affordable solutions can be developed through interdisciplinary collaboration and a commitment to addressing real-world challenges. The Shwaas ventilator is a significant contribution to the field of respiratory care, and its low-cost and accessible design has the potential to save lives and empower communities in need. Further testing and validation of the Shwaas ventilator is necessary to ensure its safety and efficacy in real-world settings.

Acknowledgments

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