Design of auto adjustable CPR assistive device for non-expertise usability scenarios

Jis Paul¹, Abraham², Divin K Davis¹, Shinu Sebastian¹, Edwin Kurian¹, Akshaya M¹

¹Department of Biomedical Engineering, Sahrdaya College of Engineering and Technology, Kodakara, Thrissur, India
²Department of Electronics and Communication Engineering, Mangalam College of Engineering, Ettumannoor, Kottayam, India

Abstract: The proposal introduces a frugal device designed to optimize cardiopulmonary resuscitation (CPR) procedures, offering a promising solution to enhance emergency medical care. In CPR, maintaining adequate chest compressions is crucial for sustaining blood circulation and oxygen supply to vital organs until professional medical help arrives. The proposed device addresses this challenge by continuously monitoring the pressure of chest compressions. When the pressure exceeds a preset threshold, the device automatically triggers the deflation of an airbag, thereby damping excess pressure and ensuring compression levels remain within the optimal range. This innovative approach not only improves the effectiveness of CPR delivery but also mitigates the risk of injury to the patient, as excessive compression force can cause rib fractures or other complications. By providing real-time feedback and assistance during CPR, the device has the potential to enhance the quality of care delivered by both trained professionals and lay rescuers, ultimately improving patient outcomes in emergency situations. Overall, the development of this frugal device represents a significant advancement in emergency medical technology, offering a cost-effective and accessible solution to optimize CPR procedures and save lives.

Keywords: CPR, dampening, Threshold

1 INTRODUCTION

Cardiopulmonary resuscitation (CPR) is an emergency life-saving procedure that can help keep oxygenated blood flowing to the brain and other vital organs until definitive medical treatment is available. CPR is important because it can double or triple a person’s chances of survival after a heart attack arrest. When someone’s heart stops beating, blood stops flowing to the brain and other vital organs. Brain damage can begin within minutes and death can occur within 10 minutes.

¹Corresponding author: jispaul@sahrdaya.ac.in

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1.1 Techniques of CPR

CPR is frequently done in conjunction with artificial ventilation or mouth-to-mouth breathing to try and manually preserve intact brain function until further measures are taken to restore spontaneous blood circulation and breathing. First step is to give them a gentle shoulder shake and shout to see if they are responsive. Then dial the local emergency number. In the event that you are not alone, ask a companion to phone for assistance while you begin CPR.

1.1.1 Chest compression

The correct way is to place the base of one hand in the middle of your breast, below the nipple line, and then interlock your fingers with the base of your other hand. The rescuer applies compression to a depth of at least 5 inches for adults and therapy for infants and children, keeping elbows straight and shoulders flat over the hands. The recommended compression rate is 100-120 compression’s per minute. It is very important to retract the chest sufficiently between compressions to ensure adequate blood flow. Physicians should minimize interference during compression’s, especially during monitoring and shocking using an external shock absorbed (AED). For trained and comfortable rescuers, coordinated breathing exercises are one option, but for untrained or unwilling rescuers, manual CPR is another method. The goal is to maintain circulation until medical help arrives or the patient can breathe comfortably. The combination of chest compression with other CPR techniques follows guidelines set by organizations such as the American Heart Association (AHA).

1.1.2 Rescue breaths

In cardiopulmonary resuscitation (CPR), rescue breathing is an important component after chest compressions. Rescuers should ventilate the patient at the recommended compression rate of 30 compressions and 2 rescue breaths. This involves breathing to provide new oxygen to the lungs. A ratio of 30:2, which means two rescue breaths for every 30 chest compressions. The purpose of breathing exercise is to support blood oxygenation and vital functions of the body. Doctors must ensure that the patient’s mouth is closed and that all breaths are performed properly to avoid unnecessary interruptions in the chest compression cycle. This combination combines chest compression with rescue breathing and is designed to provide the best possible way to stabilize the heart and increase successful resuscitation. Education and awareness of these strategies can enable people to respond effectively to cardiac events, according to guidelines from organizations such as the American Heart Association (AHA).

2 OVERVIEW

2.1 Labelling

The data collected from survey suggests the problems that need to be identified while designing a assistive CPR device. The problems being
• Comfort: The materials used for the device should not apply extra forces surrounding the chest area other than those from the compressions causing discomfort.

• Compression: The compression must provide optimum pressure so that the heart starts pumping and thereby initiating blood circulation.

• Compartments: The device consists of two compartments which are the mechanical part which performs compression and the electronic part which controls compression.

• Ease of Use: The device is frugal, lightweight and can be used by anyone even without prior training.

### 2.2 FEATURE EXTRACTION

After further observation and contemplating the needs in the new model of CPR device, we chose three main features that we will be looking into while designing the device, they are (1) Age, (2) Shoulder breadth and (3) Shoulder to Waist length.

### 3 MEASUREMENT TABLE

<table>
<thead>
<tr>
<th>AGE</th>
<th>SHOULDER BREADTH (in cm)</th>
<th>SHOULDER TO WAIST LENGTH (in cm)</th>
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</tbody>
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#### 3.1 Design Aspects

For incorporating all the features that need to be integrated into the design we need to consider certain factors:

• Biomechanical considerations: Integrating a thorough understanding of thoracic biomechanics, mathematical modelling of CPR, hemodynamics and analyzation of trans-thoracic impedance to ensure optimal support and functionality.

• Material Selection: Choosing materials that are comfortable, durable, and flexible. Ensures hypoallergenic properties for long-term use without adverse skin reactions.
• Weight and Ergonomics: Maintaining a balance between offering strong support and remaining lightweight. Ensuring ergonomic considerations to improve user comfort during daily tasks.

• Ventilation: Along with compression, rescue breaths are also to be provided with the help of Ambu-bag which restores breathing.

4 DESIGN

The CPR Assistive device works in the similar way of the conventional CPR pressure delivery by humans. Pressure is delivered onto the outer plate under which the elastic bag filled with air is placed. This bag comes in direct contact with the chest. The pressure given to the plate is directly transferred to chest. The system works by dampening the excess amount of force applied. The shape change of the self-inflating elastic bag is sensed using ultrasound sensors placed inside the bag. The deflation or shape change is directly related to the compression force given to the chest.

Whenever the horizontal air-filled section length is less than 5cm the microcontroller controls the relay accordingly, this activates the solenoids valve which releases the excess air. This process is stopped when the length becomes greater than 5cm. Normal CPR protocol involves chest compressions and ventilation in the ratio 30:2. This is controlled by an indicator which indicates the requirement of ventilation after every 30 compressions. The ventilation is given using standard Ambu-bag manually by the user. The following diagram depicts the workflow of the device.

Fig 1 Block diagram
The idea was then progressed based on the first drawing of the design.

4.1 Software

• Arduino IDE: It is a user-friendly software for programming Arduino microcontroller boards. It offers a text editor, compiler, and loader for code development, making it
accessible for beginners and popular in the maker community.

- Autodesk Fusion 360: The fusion 360 is an excellent software to design the prototypes, especially for beginner researchers. They have inbuilt component setting so that the component with user specification can be found in their database.
4.2 Hardware

- Arduino Uno: Arduino Uno is a popular microcontroller board based on the ATmega328P chip. It’s widely used for prototyping and DIY projects, offering easy interfacing with sensor, actuators, and other devices through its GPIO pins.
- Ultrasound Sensor: An ultrasound sensor, like the HC-SR04, uses ultrasonic waves to measure distance. It emits a pulse and calculates the time it takes for the signal to bounce back, providing accurate distance measurements, commonly used in robotics and proximity sensing.
- Solenoid Valve: A solenoid valve is an electromechanical device that controls the flow of liquid or gas through a pipe. When an electric current passes through the solenoid coil, it generates a magnetic field, causing the valve to open or close. Commonly used in fluid control systems.
- Relay: A relay is an electrically operated switch. It uses an electromagnet to mechanically control the switching of a circuit. Relays are crucial for interfacing high-voltage devices, such as motors or lights, with low-voltage microcontroller systems like Arduino, ensuring safety and isolation.

![Fig 2 Front view](image1)
![Fig 3 Top view](image2)
![Fig 4 Bottom view](image3)
5 LITERATURE SURVEY

5.1 Need for CPR

CPR is needed because it can sustain vital blood flow to the brain and other vital organs when someone’s heart stops beating. By performing CPR, bystanders or trained individuals can buy crucial time until professional medical help arrives, increasing the chances of survival and reducing the risk of permanent brain damage or death.

5.2 Conventional method of CPR

The conventional method of CPR involves several critical steps. First ensure the scene is safe before approaching the victim. Check the victim’s responsiveness by tapping their shoulder and calling out. If they are unresponsive, call for emergency help immediately. Check for normal breathing, and if absent or irregular, begin chest compression. Place the heel of one hand on the center of the victim’s chest and the other hand on top, then perform compression at a rate of 100-120 per minute. After 30 compressions, give two rescue breaths by tilting the victim’s head back, pinching the nose, and making a seal over the mouth. Alternate between compression and breaths until help arrives or the victim shows signs of life. If an AED is available, use it according to its instructions and resume CPR immediately afterward if advised. Proper technique and prompt action are crucial in administering effective CPR and increasing the chances of survival.1

5.3 Innovations in modern CPR techniques

Automated CPR devices and mobile apps and online training platforms offer convenient access to CPR education, empowering more individuals to learn life-saving skills. Feedback devices and mechanical CPR devices ensure optimal compression quality, reducing rescuer fatigue and improving outcomes. Telecommunicator-assisted CPR provides real-time guidance over the phone, ensuring prompt and correct CPR delivery. These innovations collectively aim to enhance the accessibility, simplicity, and efficacy of CPR, ultimately increasing survival rates for cardiac arrest victims.2

5.4 Drawbacks of existing solutions

If the compression is not deep or fast enough, it will not be effective in maintaining blood flow to the brain and other vital organs. Improper placement of hands can cause either a large effect or no effect. Hands should be placed in the middle of the chest between the nipples. Another failure is the opening of the airways. To open the airway, tilt the person’s head back and lift the chin. Too many or too few rescue breaths can alter the rhythm of CPR. Adults should receive two rescue breaths after every 30 chest compression. Infants and children should receive one rescue breath after every 15 chest compression. Rescue breaths should be given until you see the patient’s chest rise. If we blow too hard, we could inflate the person’s stomach instead of their lungs. CPR should continue until the person starts breathing on their own or until help arrives. Another
The problem identified is the non-use of an AED when available. An AED can analyze a person’s heart rhythm and deliver an electric shock if necessary.\textsuperscript{5}

Automated CPR devices can be expensive to purchase and maintain, which may limit their availability in some settings. It takes time to properly position and prepare the device before starting chest compressions. This delay can be critical in the early minutes of cardiac arrest. Even incorrect knowledge of how the device works is required, otherwise it may cause user error. These are designed to provide consistent chest compressions, but individual patients may have different chest compliance or anatomy, requiring adjustments to provide optimal CPR. They may not provide feedback on the quality of CPR provided, making it difficult to assess whether adjustments are necessary. They can cause injuries such as rib fractures, pneumothorax, or internal organ damage, especially if they are not properly aligned or used in patients with certain conditions. They may limit range of motion for other interventions such as defibrillation or airway management. A training requirement is essential. ACC devices are mechanical devices that can malfunction or fail, potentially hindering CPR efforts.\textsuperscript{6}

5.5 Need for this assistive device

A CPR assistive device could help to overcome the challenges by providing real-time feedback to the person performing CPR. The device could also help to automate some of the tasks involved in CPR, such as providing chest compression or rescue breaths. This assistive device will ensure that CPR is performed correctly and consistently even by people who are not trained or experienced.\textsuperscript{3}

5.6 Design Prototype

The data of the compression force applied by various individuals were recorded with the help of Hand dynamometer and the values were plotted as a graph using the software Vernier. The measurements were done by 32 people for the time interval 10 seconds. The resultant graph is included below. From the graph it can be interpreted that the maximum force that can be applied by an individual is 27.85 kg (nearly 30kg), which is much low compared to the required force in the CPR compression. And so, our design to produce effective compression at optimum depth and force was completed. The design now produces the compression at an optimum force and whenever the force exceeds the threshold, excess force dampens by releasing the air from the inflated airbag. The 3D design which upholds the mechanical and electrical part was also completed.\textsuperscript{4}

6 RESULT

The efficacy of the CPR assistive device in providing quality compression at required rate and amount is evaluated using FSR sensors and practical observations. The analysis involves studying A feedback system integrated into the device provides real-time information such as the indication LED light to provide two rescue breaths using Ambu-bag after every 30 compression and, facilitating instant adjustments for improved benefits. This comprehensive approach validates the device’s effectiveness and offers insights for optimization.
The final product image is included below. The protruded plate written as “PRESS HERE” is the compression plate where the rescuer will be pressing so as to deliver the compression. Pressing this plate requires minimum effect but the resultant force is according the CPR standard force of compression. Below this plate is where the airbag lies which provides the necessary force. So, whenever the force applied on the compression plate is excess, the airbag deflates by releasing excess air through solenoid valve thus the dampening occurs. The system is controlled by electrical system which monitors the force applied, the compression depth and the compression count and also indicates a message to provide rescue breaths after every 30 compressions, which is a critical part of CPR.

Fig 5 Compression force measurement graph

Fig 6 Final Image of product (Top view)

Fig 7 Final Image of product (Side view)
7 CONCLUSION AND DISCUSSION

As mentioned earlier the measurement for 3D design was estimated based on mean value calculation of body dimensions of people in the age 21-22 years. But these dimensions may vary because, in men there are chances that these measurements can increase since they are tentative to further growth. So, this average value determined will be of no use. And also, in comparison of our estimated value to anthropometric details of Asians, they vary to much larger extent. Considering people of other nation like North Americans and Africans who are expected to have much more larger body dimensions, would never fit into this device. So, a mechanism that addresses this issue in addition to height adjustment can be considered in the future. Telescopic legs are useful for height adjustments because they can extend and retract to accommodate various heights or surface. It has essential stability or functionality so that it can withstand excess force from repetitive compression.

The device now includes only the dampening part where the force exceeding the threshold value is dampened but from the compression force test, we could understand that the force applied by non-trained people or non-professionals are very low compared to the required compression rate. So, a mechanism where the force applied at a particular instant is monitored, compared with the threshold value and determine whether to amplify or dampen the applied force can be designed. The voice assistance to guide the user on the counting of compression could be included. Incorporation of AEDs along with this device can be continuation of the development of this design in the future.

References

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