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Automated Pulse Retrieval Device

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ABSTRACT
Sudden Cardiac Arrest Foundation (SCAF), based in USA has found out that leading cause of death among adults over the age of 40 in the United States and other countries is Sudden Cardiac Arrest (SCA). In India, approximately 4280 out of every one lakh people die every year from this disease. There are many cardiac assisting techniques such as cardiopulmonary resuscitation (CPR), defibrillation, advanced cardiac life support, and mild therapeutic hypothermia present to help the patient survive through SCA. Four out of ten victims survive due to cardiac assist devices following above techniques. Due to the dearth of such cardiac-assist devices and low knowledge about such devices, rate of mortality has increased in India. Highlighting the need of cardiac assist device, this paper explains and presents the design and development of a prototype model of an Automated Pulse Retrieval Device which will give chest compressions in case of sudden cardiac arrest. This is an automatic, cost effective and portable Cardio Pulmonary Resuscitation (CPR) device which will automatically compress the chest 5 inches deep and help spontaneous circulation of blood to brain and restore normal breathing and circulation. This will increase the survival rate of the patient effectively.

Keywords
Cardiac Arrest, Cardio Pulmonary Resuscitation, Automated Portable cardiopulmonary resuscitation device

1. INTRODUCTION
A “cardiac arrest” is when your heart stops beating. This is not the same as a “heart attack”, although a heart attack may lead to a cardiac arrest. There are numerous causes of cardiac arrests, such as a disturbance in the heart rhythm, drugs/poisoning, heart disease / a heart attack, traumatic injury/blood loss or anaphylaxis. If a cardiac arrest occurs, blood will stop circulating around the body. Breathing will also cease as well though it may not stop completely for several minutes. Without a supply of oxygen, the cells in the body start to die. Brain cells are incredibly sensitive, after about 4 – 5 minutes of no oxygen brain cells will begin dying leading to brain damage and death [1].

Figure 1.1 Procedure of giving Manual CPR [3]

The purpose of cardiopulmonary resuscitation (CPR) is to keep oxygenated blood flowing around the body to keep the vital organs alive. CPR itself will not restart someone’s heart; it just keeps them alive until a defibrillator arrives. A defibrillator is a device which delivers an electrical shock to the heart to restart it [3]. APR Device will be a revolutionary non-invasive cardiac support pump that moves more blood, more consistently than is possible with manual compressions. Easy to use and its load-distributing strap squeezes the entire chest thus providing circumferential pressure on the patient’s chest. As a result, victims receive more consistent, high-quality compressions than those delivered by simple automated CPR devices, which means improved blood flow. Thus, Automated Pulse Retrieval Device (APR) device using Load Distributing Strap (LDS) system will help us to give good CPR automatically to the needy than manual CPR.

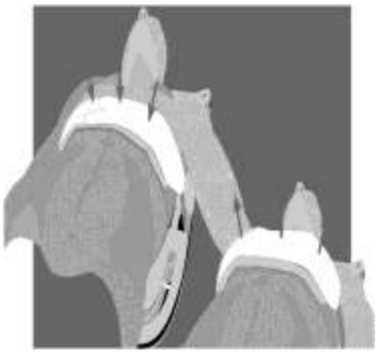


Figure 1.2 Load Distributing Band System [2]

This paper aims to aware about the dire need of having automated CPR device in the healthcare industry today in India. Absence of such a device in India is a major cause for critical loss of life in cases of sudden cardiac arrest (SCA).This type of system is installed in foreign countries like U.S.A. Canada and more than 80 other countries. Manual CPR gives us only 10-20% revival rate in contrast of automated CPR. Sadly, 90 percent of Indians may feel helpless to act during a cardiac emergency because they either do not know how to administer CPR or their training has significantly lapsed. [2] This project can provide cardiac assistance in critical cases, thus acting a boon in saving precious life.

2. LITERATURE SURVEY
In primeval times, when CPR technique was just established, it was performed manually on the required patient [4]. Some of the manual techniques then performed were Mouth to Mouth Resuscitation (16th century), Sylvester's Method Of Artificial Respiration(19th century) , Holger Nielsen technique (20th century). These were first forms of Artificial Respiration but faced much criticism due more time

consumption, un-comfort faced by the rescuer and the patient [4,5]. Lot of physical efforts taken by rescuer, therefore no continuous procedure performed on patient due to tiredness of rescuer. Only Doctors or highly trained and experienced medical personnel were required. Therefore, more number of compressions was not possible due to human fatigue. After further developments, Semi-Automated CPR Techniques were introduced to overcome manual errors. Piston Chest Compression (1960s), Vest CPR (late 1970s and early 1990s) and Active Decompression (1990s) were semi-automated CPR techniques. Through mechanical device more number of compressions was achieved hence the rate of recovery increased but Semi Automated CPR systems were bulky and created noise, these systems also needed high maintenance and it was difficult to handle by a lay man. So further, fully automated CPR devices were introduced such as Lucas (2000s) and Auto pulse (2000s) which proved beneficial to patients and proved a success in CPR techniques. [2,6]Coronary Perfusion Pressure (CPP) is an indicator of coronary flow. When CPP increases, blood flow to the myocardium also increases. The driving force for coronary blood flow (aortic pressure) decrease the pressure resisting flow (right atrial pressure) results the blood pressure gradient for that vascular bed, and blood flow is related to this pressure gradient. Measurement of CPP is an invasive research technique and is not routinely available or practical in the CPR setting. [7]A correlation was noted between CPP and the return of spontaneous circulation (ROSC) .It has been observed in a study of several patients that CPP greater than 25mm Hg had a return of spontaneous circulation, while no patient with a peak CPP of less than 15mm Hg experienced such a return. Return of spontaneous circulation and survival from an arrest have been clearly linked to the ability to achieve a CPP greater than 15mm Hg. The problem is the difficulty in achieving and maintaining CPP above 15mm Hg through conventional CPR. As the result of this observation, efforts to develop automated CPR systems for increasing myocardial perfusion during CPR have been in progress which could atleast achieve 20-25 mm Hg of pressure.[7]Taking into consideration all limitations of previous CPR techniques, this paper provides a cost effective, automated alternative solution to the process of Manual CPR and also sheds light on various challenges in achieving the end result. The paper offers a conclusion with an in depth futuristic scope and viability of the cardiac arrest devices in health care industry.

2.1 Manual CPR v/s Automated CPR

To understand the problems that are faced by paramedics while delivering Manual CPR and to then compare it with the capabilities of Automated CPR, the following table of is presented below: [2]

Table 2.1.1 Manual v/s Automated CPR

Quality CPR Requirements	**Manual CPR**	**Automated CPR**
100 compressions/minute	Difficult to perform well	Delivers 80compressions /minute
Compressions depth 1.5’’ to 2.0’’	Difficult to perform well	Exact depth can be set.
Full chest release	Difficult to perform well	Active full chest release

WHO standards specify the following conditions to be maintained for manual CPR, hence the aim was to fabricate a machine which would do at the same time circumventing the disadvantages of manual CPR.

(i) Rate of chest compressions at least 100 chest compressions per minute (administered 30 compressions at a time, pause equivalent to two breaths taken to check for resumption of pulse).

(ii)Vertical Displacements-1.5-2 inches

3. DESIGN

The basic parts of the designed APR device are:

3.1 Servo Motor - The heart of the device

Servo Motors are small in size but are very energy efficient. Because of this feature, they are used to pull load distributing strap from both the sides in the device. The servo circuitry is built right inside the motor unit and has a position able shaft, which usually is fitted with a gear (as shown below figure). The motor is controlled with an electric signal which determines the amount of movement of the shaft. Inside there is a pretty simple set-up: a small DC motor, potentiometer and a control circuit. The motor is attached by gears to the control wheel. When the motor rotates, the potentiometer's resistance changes, so the control circuit can precisely regulate how much movement there is and in which direction. When the shaft of the motor is at the desired position, power supplied to the motor is stopped. If not, the motor is turned in the appropriate direction. The desired position is sent via electrical pulses through the signal wire. The motor's speed is proportional to the difference between its actual position and desired position. So if the motor is near the desired position, it will turn slowly, otherwise it will turn fast. This is called proportional control. This means the motor will only run as hard as necessary to accomplish the task at hand [4]

Figure 2.1.1 Servo motor and its inner components[8].

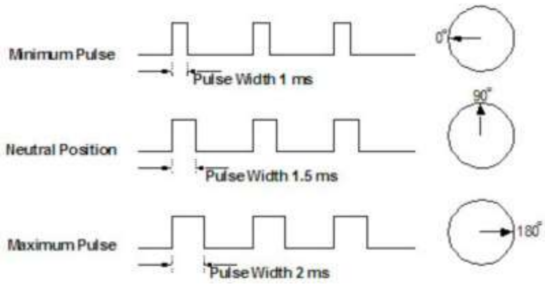


Figure 2.1.2 Variable Pulse Width Control Servo Position.[9]

When these servos are commanded to move, they will move to the position and hold that position. If an external force pushes against the servo while the servo is holding a position, the servo will resist from moving out of that position. The maximum amount of force the servo can exert is called the torque rating of the servo. The servos which are used in this project have a torque of 9 kg .Servos will not hold their position forever though; the position pulse must be repeated to instruct the servo to stay in position.

3.2 Arduino UNO Board: Controller of Device

The Arduino Uno is a microcontroller board based on the ATmega328 . It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button.

Figure 3.2.1 Arduino UNO board [Front and Back side[10].

The block diagram (figure 3.2.2) consists of the following and has specific functions to be performed:

1. Power Supply – Battery Operated.
2. Arduino UNO Board – Controls and synchronizes the working of all the components of the system. It sends the signals to the hardware components after receiving input commands from the user.
3. Design components of APR – This consists of two servo motors, power driver, load distributing strap. All of which help in achieving desired compressions. One motor is rotated in clockwise direction while the other is rotated anticlockwise direction. The power driver provides power to compress the chest to desired levels. The two motors are placed on the either side of the patient.

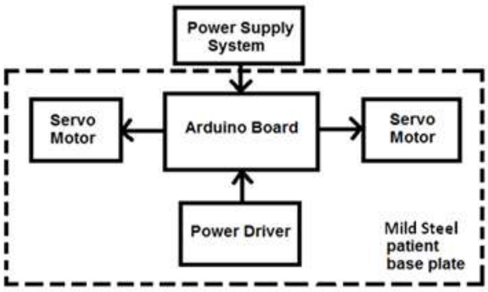


Figure 3.2.2 Block Diagram of Components mounted on the base plate

The block diagram (figure 3.2.3) for the Design of strap assembly is given below:

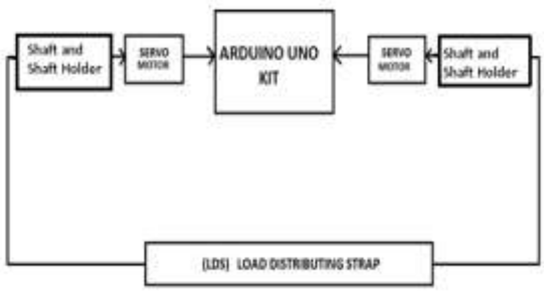
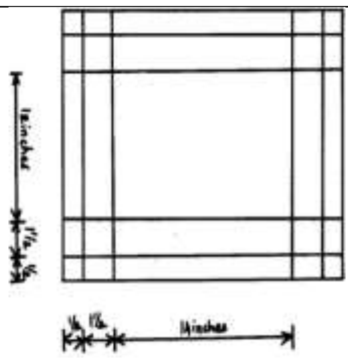


Figure 3.2.3 Design of strap assembly

Two 9 kg torque servo motors were used rotating on opposite direction of each other that 180 and -180 degree. These motors are controlled by ARDUINO UNO. This helped providing ease of movement to the LDS which is pulled and released by servo motor, attached to shaft holder.

3.3 Base Plate and Shaft Designs and Their Measurements

The base plate and shaft designs and their measurements are given in Table 3.3.1

3.4 Sr No.	3.5 Figure/ View	3.6 Description
1		**Outer dimensions of base plate (Top view)** Patient's Base Plate is placed beneath the patient. To make the base plate, a 18 x 16 inch sheet of mild steel was used which was selected taking into consideration

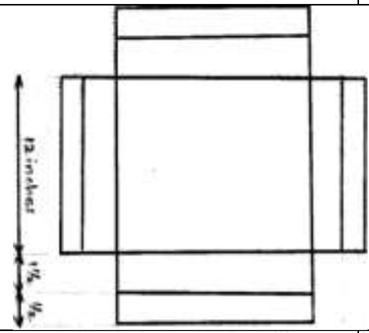
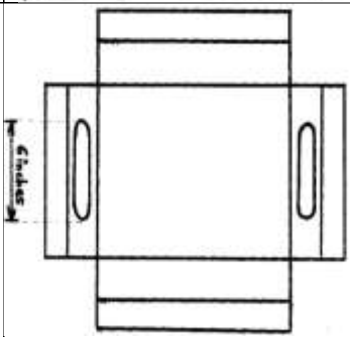
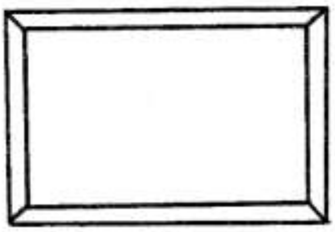
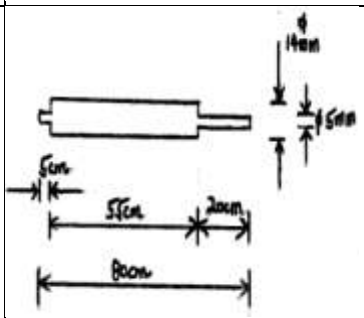
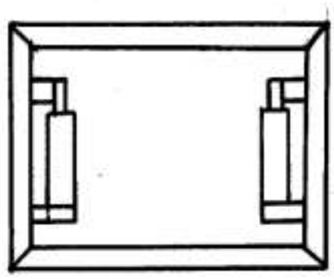
		normal human body weight (weight 100 kg).
2		**Inner dimensions of base plate (Top view)** Corners were cut off for further folding of edges.
3		**Slit dimensions of base plate case (Top View)** 6 inch slits were made on two opposite sides of the base plate for inserting the belt through these slits.
4		**Final folded base plate case (Top view)** the remaining portion of the base sheet was made into plate edges to give a case type look.
5		**PVC Shaft measurements (Side View)** The shafts are of 80 cm in length. The belt was mounted on the centre part of the shaft that is 55 cm in length. Shaft holders were placed on either side of the central part. The end part which was 5cm in length was for fitting of the motor screw.
6		**Placement of shaft and motors on the base plate (Top view)** The final design consists of two rotating shafts driven by two servo motors. The two motors moved in opposite directions. The motors are held by 90 degree stands. These motors are placed parallel to the patient's chest.

Table 3.3.1 Measurements of Base Plate

3.4 Materials Used in making the APR device

Table 3.4.1 Materials used in various parts of device

Parts Of Device	Materials (Advantages)
Base Plate	Mild Steele (light in weight)
Motor supporting stands	Aluminium (heat resistant)
Shaft	PVC (heat resistant and easily moldable)
Shaft Holder	Aluminium (sturdy and heat resistant)
Load Distributing Strap	Nylon (maintain flexibility)

The designed APR device consisted of a belt which was wrapped around the patient's chest. It was made of a Velcro strap so that it can help maintain flexibility for different patient sizes. The length of the belt will be 29 inches and the breadth will be 2 inch. It also consisted of two rotating shafts driven by two servo motors. The two motors moved in opposite directions. The motors are held by 90 degree stands. These motors are placed parallel to the patient's chest.

As the Arduino board is switched on, the signals from arduino board are sent to the servo motors and hence they start rotating in opposite direction to each other which automatically generates the movements of the patient belt through a shaft assembly. Hence the CPR's are provided to the patient through patient belt movements.

4. CONCLUSION

A prototype model of an Automated Pulse Retrieval Device was designed and developed such that it had the capability of giving chest compressions in case of sudden cardiac arrest. The designed device was an automatic, cost effective and portable Cardio Pulmonary Resuscitation (CPR) device which would automatically compress the chest 5 inches deep and help spontaneous circulation of blood to brain and restore normal breathing and circulation. This would increase the survival rate of the patient effectively.

The APR model was designed keeping in mind many factors such as materials used in making the device, dimensions of patient resting board, patient belt and the device assembly. The base plate is made of mild steel because it's light in weight and therefore the device portabilityincreases. All assembly parts such as shaft, shaft holders, motors supporting stands are madeup of heat resistant material which improves product accuracy as well as productivity, therefore the device will face minimal deformation.

Hence, the designed Automated Pulse Retrieval device using load distributing strap aspires to initiate a breakthrough revolution in providing cardiac assistance in critical cases, leading to a drastic reduction in loss of precious lives with easy to use controls that can be operated even by a lay man at the time of uncontrollable emergencies. This designed APR device will overcome problems faced while administering Manual CPR and also it can be operated by common people without any specific training.

5. FUTURE SCOPE

APR Device can be further put forward to many additions such as- it can be made battery operated, so there won't be any need to find electric connection in case of emergency and also it will cut down the electrical consumption. Automatic CPR timer system can be implemented to indicate number of CPR'S given and stop instructions of giving compressions too. Weight sensors can be added to the device so that the device adjusts its compressions according to the patient's weight. Whole device can be made operator voiced so that the operator's commands can provide assistance to people operating the instrument. Defibrillator system can be part of the APR device for emergency cases, if CPR doesn't help in revival of pulse, a handy defibrillator can be needful.

6. REFERENCES

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