Low-Cost, Small-Footprint, Barometer-Based CPR Feedback Device

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1 Background

Cardiopulmonary Resuscitation (CPR) is a recommended emergency procedure for a person who has collapsed with no signs of breathing and pulse. It consists of external cardiac massage and sometimes artificial respiration to maintain the minimum blood circulation and oxygen exchange necessary for survival until help arrives. When CPR is needed outside a hospital, most witnesses are not comfortable performing it due to lack of training or confidence. Furthermore, sustaining the essential survival baseline in an average adult requires continuous compressions of 4 cm in depth and 100 compressions per minute, which is very physically demanding. Without any feedback, even the experienced emergency responders only maintain 40% of their compressions at an adequate level due to fatigue [1].

To mitigate bystanders' hesitation and increase performance awareness in professionals, many CPR aiding devices have emerged over the years. They provide various degrees of guidance and/or feedback in compression position, rhythm, and depth. However, even though these devices improved the quality of all CPR performance [2], they are rarely found in use. Some are found inside Automated External Defibrillator (AED) kits. However, AEDs are expensive and bulky, and they primarily found in places that already have strong anticipation for heart attacks, such as nursing homes and athletic facilities. More importantly, even if an AED is nearby, CPR should start as soon as possible and continue until AED delivers the shock. Therefore, a CPR aiding device should be even more accessible than AEDs.

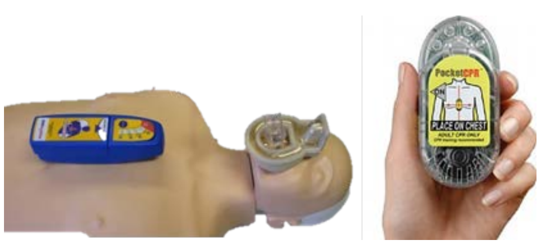

Figure 1: Example of Current Devices. *CPREzy™ (left) and Zoll® Pocket CPR (right).*

The existing CPR aiding devices range widely in size and sensor mechanisms. The mechanically simple and therefore low-cost devices, such as the spring-based CPREzy™ (Figure 1 left), are often bulky; the more sophisticated ones that use piezoelectric force sensors and accelerometers, like the Zoll® Pocket CPR device (Figure 1 right), are often expensive. However, for a device to be widely distributed and therefore easily accessible by the general public, it needs to be both small and cheap, such that it can become a standard part of first aid kits. We present a barometer-based design that is simple, small, and low-cost, thereby more likely to be widely distributed.

2 Design

The device is a small plate to be placed on the patient's sternum and underneath the provider's palms during CPR compressions. It detects and evaluates the compression and provides the user with salient visual or audio signals, such as LEDs lights of different colors or beeps of different pitches, regarding the frequency, depth, or force exerted for each compression.

The design consists of a single barometer enclosed in an airtight chamber. As seen in Figure 2, the air chamber is created by two acrylic plates, each 3mm thick, separated by a 2mm rubber ring. A single barometer (MPL115A2 by Freescale Semiconductor Inc.) is located on the edge of the chamber. A custom PCB board for the barometer is used to minimize the device's electronics footprint. To ensure air-tightness, adhesive surrounds the interfaces between the rubber and acrylic layers. For the prototype, the air-tightness was assured by the unchanged barometer readings when a constant force was applied to the air chamber.

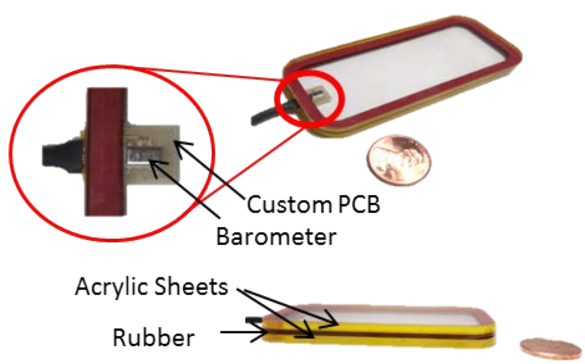

Figure 2: Device Design. *A single barometer enclosed in an airtight chamber that is created by sandwiching a rubber ring with two acrylic plates.*

When force is applied to the acrylic plates during compressions, the rubber ring deforms as a cushion but still prevents the plates from touching each other and collapsing the air chamber. The change in air pressure inside the chamber is registered by the barometer.

The air chamber makes the device less sensitive to relative positions of the exerted force and the sensor. Therefore, as long as the entirety of the force is applied on the device, which is approximately the size of the heel of an average adult's palm and can be made smaller; a single sensor can cover a large area regardless of the exact point of force exertion.

The device is also intended to incorporate an audio beat to guide the compression rhythm, LED indicator lights to show the quality of compression, and warning lights or sounds when the compressions are inadequate. But for this first prototype, all the data processing and additional features are done on a computer. An I2C to USB Bridge (CY3240, Cypress) is used to connect the sensor to the computer. The computer played a beat for rhythm guidance, and displayed screen animations of the force exerted for monitoring and warnings.

In future iterations, all the components – indicator LEDs, buzzer, battery, and signal processing – can be integrated without much change in the overall spatial design. The size of the device can also be modified since the only parameter to keep constant is the ratio of force exerted and change of air chamber volume, which can be moderated by balancing durability of the rubber and area of the plate.

The device can be made at a very low cost since the barometers are made cheaply in recent years due to their ubiquity in cell phones. The custom designed PCB with embedded LED, battery, buzzer, and simple microchips are all existing low-cost technologies. In addition, the device has very little manufacturing precision requirement. Therefore the whole device can be made for a fraction of the cost of many current ones, which have many more sensors.

3 Validation

The validation of our device is done by comparing our device to a FDA-approved CPR aid device – the CPREzy™ (Figure 1), assuming CPREzy™ has the correct range of the forces for each body type.

We put CPREzy™ directly on a scale, administered impulse forces and read the scale as the indicator lights up for each body type. For a 250-lb man, it is recorded to require approximately 120lbs of impulse force to reach the proper force.

Under the same set up, our device can detect as low as 15 lbs and does not reach saturation for even up to 190 lbs of impulse force, which implies that the device can be used for anyone between small teens and severely obese adult patients. Beyond 190 lbs, the impulse force would break our temporary airtight seal. However, the seal can be improved in future iterations by choosing chemically compatible materials for all the layers and adhesives.

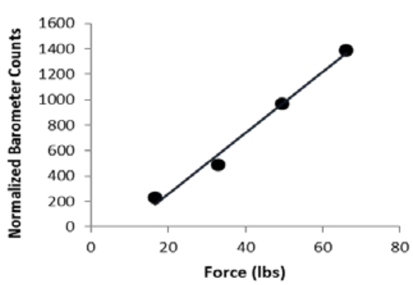

Figure 3: Force-to-Pressure conversion.

We assured the linearity of force-to-pressure conversion. For a given dimension of the plates, since area is constant, pressure measured by the barometer should be directly correlated with the force exerted, which is indeed the case (Figure 3). *A linear force-to-sensor-reading relationship and high saturation force mean that the device can be easily calibrated for a large range of body size and gender.*

Once we detach the device from the computer and incorporate the audio and visual feedback system using buzzers and LEDs, we will perform usability and performance tests in simulated CPR on manikins.

4 Conclusion

In 2008, the American Heart Association officially recommended Hands-Only™ CPR for bystanders in the event of witnessing a sudden cardiac arrest of teens and adults [3]. Hands-Only™ CPR has only two steps: call 911 and perform chest compressions. The new recommendation underscored the importance of proper compressions and eliminated the need for a ventilation component in bystander CPR aiding devices. Our single-barometer-air-chamber design is extremely small, simple, and low-cost. Not only can it be easily integrated into established emergency kits such as first-aid kits and AED boxes, but it can also be made into small personal items like keychains in order to be more accessible, or used as a training device either by using the device as part of the procedure, or embedding the device into manikins, which currently have rudimentary feedback.

Approximately 915,000 Americans will have heart attacks this year, and more than 380,000 people will die from them [4]. An easily accessible device, such as the one described in this paper, that can give any layperson or professional the guidance and feedback needed to perform CPR effectively, can be the difference between life and death for a significant number of victims.

References

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