

Mechanical CPR

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ABSTRACT

Mechanical devices for cardiopulmonary resuscitation have been in use for decades. Significant advances in the understanding of cardiac arrest physiology have led to improvements and new devices. Piston, load distribution band, active compression decompression and the impedance threshold device are discussed.

Keywords: active compression decompression, impedance threshold device, load distribution band, mechanical CPR, piston compression

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INTRODUCTION

Although modern cardiopulmonary resuscitation (CPR) was only introduced in 1960,⁽¹⁾ man has been trying to resuscitate the cardiac arrest victim for thousands of years. Mechanical aids of yore that have been tried for resuscitation included bellows, whips, barrels and trotting horses, among various other adjuncts. The aim of CPR is to restore circulation to the vital organs and the heart itself. However, standard CPR has been shown to restore only about 30% of cardiac output.⁽²⁾ Additionally, manual CPR is frequently limited by the poor performance of chest compressions by CPR providers.^(3,4)

Mechanical CPR devices, on the other hand, offer the promise of consistent, high-quality CPR. Also, the engineering of such devices may target additional physiological mechanisms to improve circulatory output. Over the years, manufacturers have incorporated ventilation into these devices and also programmed the recommended compression ventilation ratios. However, despite promising animal data and clinical studies demonstrating improved haemodynamics, return of spontaneous circulation (ROSC) and short-term survival, no device to date has been conclusively proven to be superior to standard CPR in improving survival to hospital discharge.⁽⁵⁻⁷⁾ The 2010 International Consensus Conference reviewed several devices and concluded that there was insufficient data to support or refute their use.⁽⁸⁾

MECHANICAL PISTON CPR

Within a year of the introduction of closed chest cardiac massage, a mechanical CPR device was described,⁽⁹⁾

recognising the limitations of manual CPR. Mechanical piston CPR essentially replaces the human hands with a piston mounted on an arm that is connected to a backboard or spine board that directly causes anterior-posterior compression on the sternum. The physiological mechanism employed was originally thought to be the 'cardiac pump' theory, where the heart was directly squeezed between the sternum and the thoracic vertebrae.⁽¹⁾ Subsequently, the 'thoracic pump'⁽¹⁰⁾ and the 'lung pump'⁽¹¹⁾ theories have also been proposed. Results from studies have found that mechanical piston CPR improved haemodynamic parameters,⁽¹²⁻¹⁴⁾ but not survival.⁽¹⁵⁾ The main piston device that is familiar to many is the Thumper, which has been renamed Life-Stat.

LOAD DISTRIBUTING BAND CPR

In the 'thoracic pump' theory, it is the change in intrathoracic pressures that drives the flow of blood. An early mechanical device that employed this principle was the Vest CPR, which utilised a pneumatic vest resembling a very large blood pressure cuff, worn around the patient's chest and cyclically inflated with a pneumatic pump.⁽¹⁶⁾

The Autopulse device may be considered an evolution of the Vest CPR. It uses a load distributing band that is wrapped around the patient's chest and connected to a motor built into a firm backboard. The band is then rhythmically tightened to compress the entire chest, distributing the force evenly to generate changes in intrathoracic pressure. Initial studies of the device had found improved haemodynamic parameters and coronary perfusion pressures⁽¹⁷⁻²⁰⁾ as well as improved pre-hospital survival to the emergency department.⁽²¹⁾ Subsequently, a before-and-after study found significant improvements in ROSC and survival compared with manual CPR (34.5% vs. 20.2% and 9.7% vs. 2.9%, respectively).⁽²²⁾ However a multi-site cluster-randomised trial was terminated early due to a lack of benefit and apparent harm.⁽²³⁾ It is believed that site-specific factors had led to the poorer results,⁽²⁴⁾ and further clinical research is still ongoing.⁽²⁵⁾

ACTIVE COMPRESSION DECOMPRESSION CPR (ACD-CPR)

Interest and research in ACD-CPR began after an elderly man was reported to have been resuscitated by his son using a toilet plunger on the chest.⁽²⁶⁾ The physiological basis is believed to be due to the generation of a negative

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intrathoracic pressure in diastole, thus increasing venous return to the heart.⁽²⁷⁾

The first ACD-CPR device (the Active Compression Decompression Resuscitator) is a manual hand-held device that comprised a suction cup fitted to a large disc-shaped handle. The suction cup is attached to the chest of the patient, and the operator then holds the handle using both hands, manually pushing down to compress and pulling up to decompress the chest. Several trials have found some mixed, although promising results,⁽²⁸⁻³¹⁾ but a meta-analysis⁽³²⁾ found no difference in ROSC or survival between ACD-CPR and standard CPR.

The Lund University Cardiac Arrest System (LUCAS) also employs ACD-CPR to re-expand the chest wall back to the initial uncompressed state, but not beyond that. By combining a mechanical piston with a suction cup that is applied onto the chest, it provides both active compression and decompression to the chest. It is mounted on two legs that straddle the patient and attached to the sides of a firm backboard.

Animal studies have demonstrated improved cardiac outputs, coronary perfusion pressures and end-tidal CO₂, as well as increased survival over manual CPR.⁽³³⁾ Clinical experience has been favourable,⁽³⁴⁾ although one study in the setting of emergency medical services has found no difference in ROSC or survival.⁽³⁵⁾ There have been no randomised controlled trials to date, but trials are being planned.⁽³⁶⁾

IMPEDANCE THRESHOLD DEVICE (ITD) OR IMPEDANCE THRESHOLD VALVE

By itself, the ITD is not strictly a CPR device. It is a device with a system of valves that is attached in-line with the endotracheal tube and the ventilator or manual resuscitator-bag. The valves impede airflow into the chest when air is drawn in by negative pressure during re-expansion of the chest. Air that is pushed in by positive pressure is not impeded. Air may also be expelled during chest compression. Physiologically, by slowing the inflow of air into the chest during chest re-expansion, blood is then preferentially drawn into the chest to equilibrate the pressure. Venous return, and thus cardiac output, is improved. By extension, the ITD and ACD-CPR are naturally synergistic to each other, both acting to increase venous return to the thorax together.⁽³⁷⁾

Studies combining the two have found some promising but mixed results,⁽³⁸⁻⁴⁰⁾ although a meta-analysis⁽⁴¹⁾ did not show any survival benefit. A recent randomised study published after the 2010 Consensus Conference pairing the ITD with manual ACD-CPR⁽⁴²⁾ found that 9% of patients treated with this combination survived to discharge with

favourable neurological function, compared with 6% in the control group. This effect persisted for one year, demonstrating long-term efficacy as well.

SPECIAL SITUATIONS

Despite the overall lack of strong survival benefit, there are several situations where mechanical CPR offers the advantage of relieving the human provider of performing the chest compressions. These include medical transport⁽⁴³⁻⁴⁵⁾ and during coronary intervention.⁽⁴⁶⁻⁴⁸⁾ One group has even evaluated the feasibility of mechanical CPR while acquiring brain computed tomography images for reversible causes of cardiac arrest.⁽⁴⁹⁾

COMPLICATIONS OF MECHANICAL CPR

Mechanical CPR devices are not a panacea. Complications have been described, particularly trauma to the patient.⁽⁵⁰⁻⁵²⁾ However, some might argue that manual CPR also causes injury, and that saving lives is more important. The time it takes to set up the device also leads to delays in CPR and increased the no-flow time fractions.^(53,54)

CONCLUSION

The search for an effective and safe device for resuscitation is still ongoing. The devices reviewed here are already in common use or available commercially. It is important that healthcare providers understand the physiological mechanisms that these devices are based on as well as their respective limitations, in order to maximise the benefits afforded by them.

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