

Review Article

Mechanical cardiopulmonary resuscitation for patients with cardiac arrest

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BACKGROUND: Although modern cardiopulmonary resuscitation (CPR) substantially decreases the mortality induced by cardiac arrest, cardiac arrest still accounts for over 50% of deaths caused by cardiovascular diseases. In this article, we address the current use of mechanical devices during CPR, and also compare the CPR quality between manual and mechanical chest compression.

METHODS: We compared the quality and survival rate between manual and mechanical CPR, and then reviewed the mechanical CPR in special circumstance, such as percutaneous coronary intervention, transportation, and other fields.

RESULTS: Compared with manual compression, mechanical compression can often be done correctly, and thus can compromise survival; can provide high quality chest compressions in a moving ambulance; enhance the flow of blood back to the heart via a rhythmic constriction of the veins; allow ventilation and CPR to be performed simultaneously.

CONCLUSION: Mechanical devices will be widely used in clinical practice so as to improve the quality of CPR in patients with cardiac arrest.

KEY WORDS: Cardiopulmonary resuscitation; Manual compression; Mechanical compression

World J Emerg Med 2011;2(3):165-168

DOI: 10.5847/wjem.j.1920-8642.2011.03.001

Cardiopulmonary resuscitation (CPR), also called basic life support, is an emergency medical procedure performed to restore blood flow (circulation) and breathing. The goal of CPR is to provide oxygen quickly to the brain, heart, lungs, and other organs until normal function of the heart and lung is restored. CPR can help prevent brain damage and death in children.^[1] It is reported that approximately 600 000 individuals suffer from cardiac arrest and receive cardiopulmonary resuscitation in the United States and Europe each year.^[2,3] Although modern CPR substantially decreases the mortality induced by cardiac arrest, cardiac arrest still accounts for over 50% of deaths caused by cardiovascular diseases.^[4]

The success rate of CPR ranging widely from 5% to 10% is based on many factors such as (1) causes of cardiac or respiratory arrest; (2) underlying health conditions of victims; (3) time elapse between arrest and CPR; and (4) techniques for CPR.^[5,6] The survival rate

is affected not only by CPR but more importantly by its quality. Effective CPR can contribute more blood flow to the brain, heart and other organs, and thus increase the survival rate of patients with cardiac arrest.^[7] In November 2005 the AHA revised CPR guidelines to emphasize chest compression and its effect on blood pressure.^[8] Studies^[7,9,10] showed that by taking fewer breaks between compressions, rescuers can keep blood pressure higher, which helps to pump blood to the brain and other vital organs. However, during CPR even with the best manual chest compressions, cardiac output is approximately 20% to 30% of normal value, and performer's fatigue may also reduce the quality of the compressions. Besides, chest compressions can not be performed during the transportation of patients, which prolong the time between the arrest and CPR, and also increase the difficulty of resuscitation.^[11,12] Therefore, to avoid or reduce these negative factors and to improve the

CPR quality, mechanical devices are frequently used.

In this article we address the current use of mechanical devices during CPR, and also compare the CPR quality between manual and mechanical chest compression.

Comparison of quality between manual and mechanical CPR

In 1961, Harrison-Paul^[13] applied the electric pneumatic device clinically, and then Kouwenhoven et al^[14] introduced closed chest cardiac massage for CPR in 1969. The Kouwenhoven technique has been shown repeatedly its clinically inefficacy. Although this technique can clearly save lives, its inherent inefficiency and the challenges related to teaching and retaining the skills needed to perform the technique correctly have limited its overall effectiveness. This has prompted us to develop new life-saving CPR techniques and devices.

At present, the most commonly used mechanical chest-compression devices include LUCASTM, Autopluse, Lifebelt, Thumper and Brunswick-TM HLR R30. Compared with manual compression, mechanical compression can: (1) often be done correctly, and thus can compromise survival; (2) potentially improve the quality of chest compression with automatic mechanical devices, which can potentially apply compression more consistently than manually; (3) can provide high quality chest compressions in a moving ambulance, which is very difficult to accomplish with manual CPR; (4) allow a reduction in a number of emergency medical systems (EMS) personnel needed to perform resuscitation;^[15] (5) allow ventilation and CPR to be performed simultaneously; (6) enhance the flow of blood back to the heart via a rhythmic constriction of the veins.^[16]

Autopulse can markedly increase the mean systolic blood pressure from 72 mmHg to 106 mmHg, and the average diastolic blood pressure from 17 mmHg to 23 mmHg as compared with manual compression ($P<0.05$). In addition, Autopulse can obviously improve coronary perfusion, and generate approximately 36% of the normal blood flow, which is much higher than that generated by manual compression (13%).^[17] But before and after use of Autopulse, there is no significant difference in the pressure of end tidal carbon dioxide (PETCO₂), which serves as an important parameter for evaluating cardiac output and pulmonary blood flow.^[18] Axelsson et al^[5] reported that in 126 patients who participated in the study, 64 were enrolled in a mechanical chest compression group and 62 in a control group. The group receiving mechanical ACD-CPR showed highest PETCO₂ values in contrast to the average ($P=0.04$), initial ($P=0.01$) and minimum ($P=0.01$) values. There was no

significant difference in the maximum values between the two groups. This indicated that chest compression can increase blood supply to the heart and lung.

Comparison of survival rate

Although mechanical CPR can increase cardiac output, coronary and cerebral blood flow, arterial blood pressure, and PETCO₂, whether mechanical CPR can increase the survival rate of patients with cardiac arrest is still in debate. Skogvoll et al^[19] reported that there were no significant differences between mechanical and manual CPR compression (survival rates 13% vs. 12%) in 302 patients with cardiac arrest. Another prospective trial showed that the survival rate of patients after hospitalization for 24, 48, and 72 hours and the number of patients who had reestablished spontaneous circulation was increased in the mechanical compression group, but no differences were observed between the mechanical and manual CPR compression groups.^[18] In a prospective randomized trial conducted by Kouwenhoven^[14], 1410 patients received mechanical CPR and 1456 received manual CPR. The survival rate of the mechanical CPR group was significantly higher than that of the manual CPR group (23.8% vs. 20.6%, $P<0.05$). Ong et al^[17] also reported that mechanical CPR increased the survival rate of patients. But Skogvoll et al^[19] described in their randomized clinical trial that mechanical CPR increased the mortality of patients. Thus further clinical studies or animal experiments are needed to confirm this finding.

Mechanical CPR in special circumstance Percutaneous coronary intervention (PCI)

In most cases, cardiopulmonary arrest is derived from the heart. Myocardial ischemia caused by acute coronary occlusion can lead to the development of ventricular fibrillation. PCI was thought to be useful in patients with acute ST elevation myocardial infarction (STEMI),^[20,21] and it was also beneficial to patients after recovery of spontaneous circulation.^[22] Sunde et al^[23,24] found that the mortality of patients treated with PCI ($n=12$) was significantly lower than that of patients treated conservatively ($n=20$) (17% vs. 70%). However, PCI is seldom used in patients with cardiac arrest.^[25] CPR is still required to perform PCI during cardiac arrest, but it is very difficult to simultaneously perform manual CPR and PCI. Mechanical chest compression allows for continued PCI despite ongoing cardiac or circulatory arrest with artificially sustained circulation. A study^[25] reported that in 3058 patients treated with PCI for ST-elevation myocardial infarction (STEMI), 118 were in cardiogenic shock and 81 required defibrillation.

LUCAS was used in 38 patients, 1 underwent a successful pericardiocentesis, and 36 were treated with PCI. Eleven of these patients were discharged alive in good neurological conditions. Similarly, other studies have shown that it is feasible to perform mechanical CPR during PCI.^[26-29]

Transportation

During ambulance transport to hospital, it may not be possible to perform manual CPR, while mechanical devices may play an important role in maintaining circulation.

Other fields

Mechanical devices have been used in imaging diagnosis. Agostoni et al^[30] evaluated both CT image quality in a phantom study and feasibility in an initial case series using automated chest compression (A-CC) devices for cardiopulmonary resuscitation (CPR), and they found under CPR conditions multidetector CT diagnostics supports either focused treatment or the decision to terminate efforts.

Limitations of mechanical CPR

Delayed time-elapse between arrest and CPR

Device use may delay the time-elapse between arrest and CPR. Ong et al^[31] reported that LUCAS device delayed CPR for 2.9±2.1 minutes when compared with manual compression. Another study showed that the median no-flow time, defined as the sum of all pauses between compressions longer than 1.5 seconds, during the first 5 minutes of resuscitation, was manual CPR 85 seconds (interquartile range [IQR] 45 to 112 seconds) versus mechanical CPR 104 seconds (IQR 69 to 151 seconds). The mean no-flow ratio, defined as no-flow time divided by segment length, was manual 0.28 versus mechanical CPR 0.40 (difference=-0.12; 95% confidence interval -0.22 to -0.02). However, from 5 to 10 minutes into the resuscitation, the median no-flow time was manual 85 seconds (IQR 59 to 151 seconds) versus mechanical CPR 52 seconds (IQR 34 to 82 seconds) and the mean no-flow ratio manual 0.34 versus mechanical CPR 0.21 (difference=0.13; 95% confidence interval 0.02 to 0.24). The average time to apply mechanical CPR during this period was 152 seconds. This suggests that in the first 5 minutes, the quality of manual CPR is higher than that of mechanical CPR; while during 5-10 minutes, the quality of mechanical CPR was improved. Hallstrom et al^[19] reported that use of an automated LDB-CPR device as used in this study was associated with worse neurological outcomes and a trend toward worse survival than manual CPR. These factors might partly explain the varied outcomes treated with mechanical CPR.

Injuries associated with mechanical CPR

Mechanical chest compression can also cause injuries in patients. Hallstrom et al^[32,33] reported that fracture was present in 10/47 in the manual group and in 11/38 in the LUCAS group ($P=0.46$), and there were multiple rib fractures (> or =3 fractures) in 13/47 in the manual group and in 17/38 in the LUCAS group ($P=0.12$). Bleeding in the ventral mediastinum was noted in 2/47 and 3/38 in the manual and LUCAS groups respectively ($P=0.65$), retrosternal bleeding in 1/47 and 3/38 ($P=0.32$), epicardial bleeding in 1/47 and 4/38 ($P=0.17$), and hemopericardium in 4/47 and 3/38 ($P=1.0$), respectively. This finding indicates that mechanical chest compression with the LUCAS device appears to be associated with the same variety and incidence of injuries as manual chest compression. For the injuries caused by mechanical CPR, we still need further clinical studies.

In conclusion, mechanical devices will be widely used in clinical practice so as to improve the quality of CPR in patients with cardiac arrest.

Funding: None

Ethical approval: None

Conflicts of interest: No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subjects of this article.

Contributors: Jiang L proposed and wrote the first draft. All authors contributed to the design and interpretation of the study and to further drafts. Zhang JS is the guarantor.

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Received February 10, 2011

Accepted after revision July 16, 2011