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CLINICAL PAPER

Miniaturized mechanical chest compressor: A new option for cardiopulmonary resuscitation☆

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Summary
Aim of study: After cardiac arrest, uninterrupted chest compressions with restoration of myocardial blood flow facilitates restoration of spontaneous circulation. We recognized that this may best be accomplished with a mechanical device and especially so during transport. We therefore sought to develop a lightweight, portable chest compressor which may be carried on the belt or attached to the oxygen tank typically carried on the back of the first response rescuer. A miniaturized pneumatic chest compressor (MCC) weighing less than 2 kg was developed and compared with a currently marketed ''Michigan Thumper®'', which weighed 19 kg. We hypothesized that the 2 kg, low profile, portable device will be as effective as the standard pneumatic Thumper® for restoring circulation during CPR.
Material and methods: Ventricular fibrillation was electrically induced in 10 domestic male pigs weighing 39 ± 2 kg, and untreated for 5 min. Animals were then randomized to receive chest compressions with either the MCC or the Thumper®. After 5 min of mechanical chest compression, defibrillation was attempted with a 150 J biphasic shock. Coronary perfusion pressure (CPP) and end tidal PCO_2 ($EtPCO_2$) were measured by conventional techniques together with right carotid artery blood flow (CBF).
Results: Four of five animals compressed with the Thumper® and each animal compressed with the MCC were successfully resuscitated. No significant differences in CPP, $EtPCO_2$, CBF and post-resuscitation myocardial function were observed between groups. Resuscitated animals survived for more than 72 h without neurological impairment.
Conclusion: The low profile, 2 kg miniaturized chest compressor is as effective as the conventional Thumper® in an experimental model of CPR.

☆ A Spanish translated version of the summary of this article appears as Appendix in the final online version at 10.1016/j.resuscitation.2007.07.004.

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Introduction

Cardiovascular disease continues to be the leading cause of death and more than 400,000 Americans and 700,000 Europeans are victim of cardiac arrests each year.[1] Despite major efforts to improve outcomes from cardiac arrest, fewer than 5% of victims are hospital survivors.[2–5] Both in heavily populated larger cities and in sparsely populated rural communities, delayed response by emergency medical services compromises outcomes such that survival is even more disappointing, namely as low as 1%.[6,7]

There is now evidence that the highest priority of intervention is to re-establish systemic blood flow promptly by external chest compression and thereby achieve and maintain threshold levels of coronary and cerebral perfusion. Accordingly, effective, consistent and uninterrupted chest compression is now designated as the primary intervention for management of cardiac arrest. Both survival and neurological recovery are contingent upon initiating chest compression within less than 5 min.[8–10] Accordingly, bystander initiated chest compressions by minimally trained, non-professional rescuers subsequently supported by well organized professional emergency medical providers have significantly increased survival from out-of-hospital cardiac arrest.[11–13]

In addition to the benefits of prompt intervention, it is also the quality of chest compressions delivered in both in- and out-of-hospital settings, which has proven to be a determinant of outcomes. Even well-trained professional providers cannot maintain effective chest compression for intervals that exceed 2 min.[14–17] This limitation is in addition to the documented inconsistency of depth and rate of compressions.[18–20] The challenges are even greater during evacuation and transport of victims. Therefore, the option of using mechanical devices is attractive. Mechanical chest compression potentially overcomes operator fatigue, slow rates of compression, and inadequate depth of compression. A mechanical compressor would also allow for the delivery of an electrical shock without interruption of manual compression for the protection of the rescuer.

The present study in a porcine model was therefore undertaken to compare the effectiveness of a newly developed miniaturized pneumatic chest compressor (MCC) with that of a conventional and commercially available compression device (Figure 1). The MCC was so designed that it may be carried on the belt or attached to the oxygen gas tank carried routinely by the professional rescuer. It is pneumatically powered with oxygen or compressed air. In Table 1, the principal features of the two devices are compared. The biomedical engineering details of design, construction, and pneumatic operation of the MCC will be addressed in detail in a separate medical engineering publication.

We tested the hypothesis that such a lightweight device would be as effective as a current standard, the Thumper® (Model 1004, Michigan Instruments, Grand Rapids, MI), for restoring circulation during CPR after cardiac arrest.

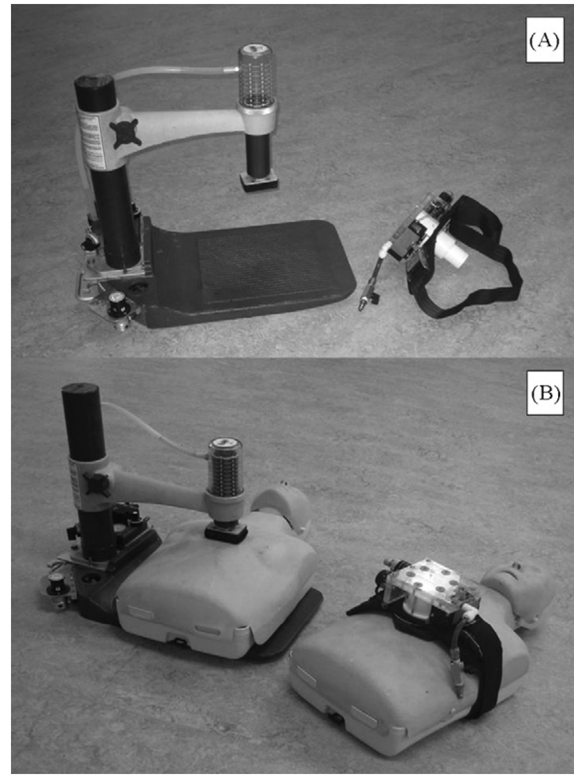

Figure 1 (A) The Michigan Thumper® shown on the left and the MCC on the right. (B) The Michigan Thumper® applied to a manikin on the left and the MCC applied to a manikin on the right.

Materials and methods

All animals received humane care in compliance with the ''Principles of Laboratory Animal Care'' formulated by the National Society for Medical Research and the *Guide for the Care and Use of Laboratory Animals* prepared by the Institute of Laboratory Animal Resources and published by the National Institutes of Health (NIH publication 86-32, revised 1985). The protocol was approved by the Institutional Animal Care and Use Committee of the Weil Institute of Critical Care Medicine. The animal laboratories of the Weil Institute are fully accredited by American Association for Accreditation of Laboratory Animal Care (AAALAC) International.

Table 1 A comparison of the features of the two chest compression devices

	MCC	Thumper®
Weight (kg)	2	19
Length (cm)	35	61
Width (cm)	15	30
Height (cm)	9	139.5
Force at pneumatic pressure of 50 psi (kg)	48	55
Gas consumption (L/min)	46	45
Compression rate (compressions/min)	90 ± 5	90 ± 5
Maximal piston descent (cm)	10	10