Effectiveness of Mechanical Versus Manual Chest Compressions in Out-of-Hospital Cardiac Arrest Resuscitation: A Pilot Study

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A prospective, randomized effectiveness trial was undertaken to compare mechanical versus manual chest compressions as measured by end-tidal CO₂ (ETCO₂) in out-of-hospital cardiac arrest patients receiving advanced cardiac life support (ACLS) resuscitation from a municipal third-service, emergency medical services (EMS) agency. The EMS agency responds to approximately 6,700 emergencies annually, 79% of which are cardiac arrests in 1994, the study year. Following endotracheal intubation, all cardiac arrest patients were placed on 100% oxygen via the ventilator circuit of the mechanical cardiopulmonary resuscitation (CPR) device. Patients were randomized to receive mechanical CPR (TCPR) or human/manual CPR (HCPR) based on an odd/even day basis, with TCPR being performed on odd days. ETCO₂ readings were obtained 5 minutes after the initiation of either TCPR or HCPR and again at the initiation of patient transport to the hospital. All patients received standard ACLS pharmacotherapy during the monitoring interval with the exception of sodium bicarbonate. CPR was continued until the patient was delivered to the hospital emergency department. Age, call response interval, initial electrocardiogram (ECG) rhythm, scene time, ETCO₂ measurements, and arrest outcome were identified for all patients. Twenty patients were entered into the study, with 10 in each treatment group. Three patients in the TCPR group were excluded. Measurements in the HCPR group revealed a decreasing ETCO₂ during the resuscitation in 8 of 10 patients (80%) and an increasing ETCO₂ in the remaining 2 patients. No decrease in ETCO₂ was noted in the TCPR group, with 4 of 7 patients (57%) actually showing an increased reading and 3 of 7 patients (43%) showing a constant ETCO₂ reading. The differences in the ETCO₂ measurements between TCPR and HCPR groups were statistically significant. Both groups were similar with regards to call response intervals, patient ages, scene times, and initial ECG rhythms. One patient in the TCPR group was admitted to the hospital but later died, leaving no survivors in the study. TCPR appears to be superior to standard HCPR as measured by ETCO₂ in maintaining cardiac output during ACLS resuscitation of out-of-hospital cardiac arrest patients. (Am J Emerg Med 1998;16:289-292. Copyright © 1998 by W.B. Saunders Company)

Recently, the effectiveness of basic cardiopulmonary resuscitation (CPR) in out-of-hospital cardiac arrest has come under scrutiny.\(^1\) Several studies suggest that continually effective CPR is not possible in the out-of-hospital setting, especially in an ambulance or helicopter.\(^1\) This is reported at a time when the importance of timely and appropriate CPR for successful resuscitation from cardiac arrest is being emphasized\(^5,9\) and the dismal outcome for patients not successfully resuscitated in the field is being realized.\(^10,12\)

It has been suggested that end-tidal CO₂ (ETCO₂) measurements are reflective of the quality of CPR and, at times, can be a valuable predictor of prognosis for patients in cardiac arrest.\(^13,20\) In addition, the use of a mechanical CPR device has been shown to produce higher ETCO₂ readings as compared with basic CPR done by health care workers. The application of the mechanical device, however, was not well controlled for in these other studies.\(^21,22\)

It was the purpose of this study to compare the effectiveness of mechanical versus basic CPR, as measured by ETCO₂ in out-of-hospital cardiac arrest patients undergoing advanced cardiac life support (ACLS) resuscitation.

MATERIALS AND METHODS

The study occurred in a suburban, municipal, third-service, all-ACLS emergency medical services (EMS) system serving approximately 220,000 citizens by day and 76,000 citizens after business hours. All emergency personnel (EMT-Ps) are American Heart Association ACLS-certified and every sudden death event is attended to by no less than two EMT-Ps and an EMT-P supervisor. The EMS system employs an E-911 call-taking process, and dispatching is done according to the Medical Priority Dispatch® program.\(^21\) In 1994, the year in which the study took place, the EMS system responded to approximately 6,700 patient encounters with a subset of 79 cardiac arrest patients.

The study design was prospective, with odd/even day randomization. Odd/even randomization was chosen over true randomization because of the limitations in the dispatching center and to facilitate patient enrollment by the EMT-Ps. Adult patients older than 16 years of age with sudden death unrelated to trauma were eligible for inclusion. Odd-day patients received mechanical CPR performed by a commercially available, pneumatically driven device at a set rate of 80 compressions per minute (Thumper\(^\circ\)). Michigan Instruments, Grand Rapids, MI (TCPR group) and even-day patients received basic human/manual CPR (HCPR group). Both began with the recognition of pulselessness by the emergency personnel. All EMT-P supervisors were in-service by a representative from Michigan Instruments before initiation of the study to assure uniformity in the application of the Thumper® by emergency personnel. The device was positioned so that the downward force of the mechanical arm was applied to the sternum. The
The patient’s body was placed between the arm delivering the compressions and the backboard of the Thumper®. The depth of compressions was determined according to the manufacturer’s recommendations of 20% to 25% of the patient’s anterio-posterior chest diameter to displace one fifth of the chest wall or approximately 1.5 to 2.0 inches. HCPR was performed by emergency personnel, who were all certified in basic CPR.

All patients were placed on the Thumper® backboard and received mechanical ventilation from the ventilation portion of the Thumper® device regardless of the type of CPR being performed. In the HCPR group, chest compressions were synchronized by the inactivated but audible pneumatic compression device, also set at a rate of 80 per minute.

ETCO₂ monitoring was performed with a digital monitor (Capnogard Model 1265; Novametrix, Wallingford, CT). Two sequential ETCO₂ measurements were obtained. The first reading was obtained 5 minutes after the intubated patient was placed on the ventilator and was receiving CPR, and the second was at the time of initiation of transport to the hospital emergency department (ED). These two data points were chosen in an attempt to isolate the effectiveness of the two CPR methods in the out-of-hospital resuscitation of these patients. Continuous ETCO₂ readings were not obtained because of the potential for variability and interruption in ventilation during the carrying and transport of these patients. ETCO₂ measurements were obtained by the EMT-P supervisor only, who had received study protocol and equipment training, including calibration of the ETCO₂ monitor.

TCPR or HCPR was continued until either the patient was placed in the care of the ED staff or the patient had a return of spontaneous circulation (ROSC). Standard ACLS pharmacotherapy was employed during the out-of-hospital resuscitation, with the exception of sodium bicarbonate.

Age, call response interval, initial electrocardiogram (ECG) rhythm, ETCO₂ measurements, scene time (arrival at patient location until initiation of transport to the ED), and arrest outcome were identified for all patients. A two-tailed Student t test was used to compare the two groups of patients, with the alpha set at .05. The findings of other studies, 2,22 Unlike other studies, however, our study attempted to examine the use of TCPR early in the resuscitation of cardiac arrest patients, specifically during the out-of-hospital phase of care, when the chances for survival would be optimal. 10-12

Although there was no significant difference in outcome between the patients in either group in this study, the results suggest that TCPR produces better cardiac output, as measured by ETCO₂ in ACLS resuscitation of out-of-hospital cardiac arrest. The sustained and increased levels of ETCO₂ for the group of patients receiving TCPR is consistent with the findings of other studies. 2,4,22 Unlike other studies, however, our study attempted to examine the use of TCPR early in the resuscitation of cardiac arrest patients, specifically during the out-of-hospital phase of care, when the chances for survival would be optimal. 10-12

Although the exact mechanism of action of CPR production of cardiac output may still be deliberated, 25 the concept of early CPR for victims of sudden death to enhance survival is not contested. 6,6 In light of the recent recognition that unsuccessful out-of-hospital cardiac arrest resuscitation infrequently results in a different outcome in the ED, the importance of ensuring the effectiveness of each link in the “Chain of Survival” is paramount. 5,10-12 While the early application of bystander CPR has been shown to have a

### RESULTS

Twenty patients met the study criteria and were entered, with 10 patients in each group. Three patients in the TCPR group were subsequently excluded, two because the ETCO₂ monitor battery failed before the second reading and one because of inadvertent extubation between readings.

Measurements in the HCPR group revealed a decreasing ETCO₂ during the out-of-hospital resuscitation in 8 of 10 patients (80%) and an increasing ETCO₂ in 2 of 10 patients (20%) (Figure 1). No decrease was measured in the TCPR group, with 4 of 7 patients (57%) showing an increased ETCO₂ and 3 of 7 patients (43%) demonstrating a constant ETCO₂ (Figure 2). The differences in ETCO₂ measurements between the TCPR and HCPR groups was statistically significant (P < .04). The ETCO₂ measurements occurred within the scene time interval, which was on average 27 minutes for all patients.

Both the TCPR and HCPR groups had an average scene time of 27 minutes as well as similar call response intervals, patient ages, and initial ECG rhythms (Table 1). Only one patient in the TCPR group was resuscitated and admitted to the hospital; this patient died within the next 48 hours. No other patient in the study was successfully resuscitated by the emergency personnel or the ED staff. These data are displayed in an Utstein Style template 24 in Figure 3.

### DISCUSSION

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### Table 1: Study Group Comparisons

<table>
<thead>
<tr>
<th></th>
<th>TCPR</th>
<th>HCPR</th>
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<tbody>
<tr>
<td>No. of patients</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Response interval (min)</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Scene time (min)</td>
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<td>27</td>
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<tr>
<td>Initial patient ECG</td>
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<tr>
<td>V-Fib</td>
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<td>4</td>
</tr>
<tr>
<td>Asystole</td>
<td>3</td>
<td>2</td>
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<tr>
<td>PEA</td>
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<td>4</td>
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**Abbreviations:** V-Fib, ventricular fibrillation; PEA, pulseless electrical activity.
positive effect on cardiac arrest resuscitation outcome,5-9 recent studies have proffered that effective CPR by emergency personnel might not always be possible in the back of an ambulance or helicopter.1-4 Our study attempted to determine if the early application of a mechanical device could be an effective means of delivering CPR as measured by ETCO2 and if the outcome for the patients receiving TCPR during out-of-hospital ACLS resuscitation could be improved.

Similar to the work by Ward and colleagues,22 we found that ETCO2 measurements were higher in the TCPR group. TCPR was applied in our study as soon as pulselessness was recognized in the field, rather than at the end of unsuccessful ED resuscitation as in the study by Ward and others.22,26 Furthermore, our patients were randomized and no cross-over between groups occurred. Our results demonstrate a sustained or increased ETCO2 with TCPR, but without a difference in patient outcome between the two study groups. The one patient in our study with the greatest increase in ETCO2 measurements was the only one to have ROSC in the field, but this patient later died in the hospital.

The search for improved delivery of CPR has lead to the clinical and bench investigation of a variety of devices and maneuvers.33-42 In addition, the well-documented decline in competency of both bystander and emergency personnel CPR provider skills33-49 argues favorably for a mechanized CPR device. The Thumper56, although not well studied in a variety of venues, does seem to represent a device that accomplishes a higher ETCO2 and, therefore, has the potential to be effective in improving outcomes for sudden cardiac death patients.

Because of the complex and adverse nature of the out-of-hospital environment, and the multifaceted nature of cardiac arrest resuscitation in the field, it makes sound medical sense that the more variables that can be controlled for, the more favorable the outcome of resuscitation from sudden cardiac death. Our study attempted to isolate the effectiveness of mechanical chest compression, while ventilation was constant and controlled for in both study groups. Other authors have emphasized the importance of controlling ventilation with portable transport ventilators in order to optimize minute ventilation.27,50,51 For purposes of accurately measuring ETCO2, a constant minute ventilation would be important.

There are several limitations to this study. First, the sample size is small and from one EMS system. After 10 months of study, the EMT-P supervisors reported to the investigators that the use of the Thumper in the HCPR group was cumbersome; specifically, the inactive compression arm of the device, which serves as the oxygen reservoir for the ventilator, interfered with patient access. It was not possible to remove the oxygen reservoir because that would have negatively affected FiO2. In addition, the emergency personnel greatly favored the manpower efficiency gained with using the TCPR and recognized the trend of improved ETCO2. Our experience and that of other EMS researchers is that the enthusiastic support of the emergency personnel is essential for successful out-of-hospital research.52,53 These factors compelled the investigators to stop the study and implement the TCPR device on every cardiac arrest patient. Second the randomization was limited to an odd/even day rotation because the nature of our dispatch system did not permit for true randomization at the time of each patient encounter. In addition, we were unable to control for the number of different emergency personnel providing HCPR and the interval that they relieved each other to prevent fatigue.

Based on the results presented, it would appear that TCPR was superior to HCPR in maintaining cardiac output, as measured by ETCO2, in out-of-hospital cardiac arrest patients. With all other measurable factors similar between study groups, the benefit of TCPR appears to be sustained and higher ETCO2 during the out-of-hospital phase of resuscitation from sudden death. Future studies should include larger numbers of patients from multiple EMS systems to demonstrate a more discernable difference in patient outcome and to address clinical effectiveness and applicability for out-of-hospital resuscitation.

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