**Efficacy of Bystander Cardiopulmonary Resuscitation and Out-of-Hospital Automated External Defibrillation as Life-Saving Therapy in Commotio Cordis**

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We report a child who sustained commotio cordis after being struck by a baseball, and offer documentation of the advantages of having readily available access to bystander cardiopulmonary resuscitation (CPR) and an automated external defibrillator (AED). We suggest that communities and school districts reexamine the need for accessible AEDs and CPR-trained coaches at organized sporting events for children. *(J Pediatr 2005;147:863-6)*

Sudden death during competitive sports in childhood is commonly due to cardiovascular causes. This phenomenon is most often linked to undiagnosed structural or electrical cardiac abnormalities, such as hypertrophic cardiomyopathy, coronary artery anomalies, myocarditis, and congenital prolongation of the QTc interval.1 However, sudden death may also occur in individuals with no underlying cardiac disease who have been struck by a projectile over the anterior left hemithorax. In this phenomenon, known as commotio cordis (CC), the impact of the projectile generally triggers ventricular tachycardia or fibrillation and subsequent cardiac arrest.

Because of the sudden nature of this insult, as well as the relative lack of aggressive resuscitation in the immediate moments after the trauma, the survival rate for CC is only 16%.2 Survival is more likely when bystander cardiopulmonary resuscitation (CPR) and the use of an automated external defibrillator (AED) is initiated within 3 minutes of the cardiac arrest. This sequence of events has been reproduced in an animal model, which demonstrated that AEDs had 98% sensitivity for detecting ventricular fibrillation and produced 100% termination of the arrhythmia in swine struck with a baseball.3

Because of the known pathophysiology of CC and the results of the aforementioned animal study, the practice of making AEDs available at competitive sporting events for children appears to be supported in the medical literature. However, for a number of reasons, including the cost of these devices, AEDs are rarely found in these settings. Clinical proof of these devices’ efficacy in life-saving situations should support the widespread purchase of AEDs and training of personnel in their use. We report a case of CC in a child at a Little League baseball game with documented evidence of the effectiveness of rapid bystander CPR followed by prompt defibrillation using an AED, a combination that led to an excellent outcome.

**CASE REPORT**

A healthy 13-year-old male with a past medical history of an “innocent” heart murmur (and a structurally normal heart as documented by echocardiography) sustained a blow to the lateral chest wall from a pitch while batting in an organized baseball game. He was reported to have taken a few steps away from home plate, at which point he collapsed. Bystander CPR, including both chest compressions and mouth-to-mouth resuscitation, was immediately started by his coaching staff, who were trained in basic life support (BLS), and the emergency medical system was activated. The paramedics arrived 6-8 minutes after the event and immediately placed the child on an AED monitor. The child was determined to be in ventricular fibrillation (Figure 1), and the AED recommended...
defibrillation, which was then delivered (at 200 joules). Subsequently, the child converted to sinus rhythm (Figure 1). At this point he also regained a palpable pulse with a rate of 80 bpm. Two minutes later, his rhythm strip demonstrated normal sinus rhythm with ST depression. Because of continued unresponsiveness, the child was intubated and transported to a local emergency room, where he initially displayed decerebrate posturing. He was stabilized and transferred to our pediatric intensive care unit (PICU) for further treatment. Physical examination on admission revealed unremarkable cardiac findings, except for a soft systolic murmur. His left lateral chest wall had an area of ecchymosis measuring approximately 4 cm in diameter (Figure 2). Within 1 hour after his arrival at our PICU, he was awake and following commands, and he was extubated soon thereafter. His neurologic examination at that point was normal, and it remained normal throughout his remaining hospital course. His initial laboratory evaluation revealed a creatinine phosphokinase level of 471 U/L (normal, 30 to 180 U/L) with an MB mass of 9 ng/mL (normal, 0 to 5 ng/mL). His serum troponin-I level was 5.4 ng/mL (normal, < 2.0 ng/mL), which peaked at 8.0 ng/mL 7 hours after admission. Within 60 hours of PICU admission, all of these cardiac markers were within normal ranges (Figure 3).

The patient’s initial echocardiogram revealed a structurally normal heart with normal biventricular function. A cardiac magnetic resonance imaging study revealed no findings suggestive of right ventricular dysplasia. A maximal exercise stress test performed on hospital day 3 was within normal limits. A 24-hour Holter monitor was placed before discharge and demonstrated only a single premature ventricular contraction. The patient was discharged on hospital day 3. Of note, he has subsequently been found to have persistence of Q-wave voltage consistent with anterior myocardial loss and/or damage; however, subsequent echocardiograms have not found any regional wall motion abnormalities consistent with this entity. Furthermore, no further ventricular ectopy has been noted.

**DISCUSSION**

Although there have been two other on-field cases (a 13-year-old batter and a 38-year-old umpire) in which ventricular fibrillation caused by CC was terminated by an AED,2 there is a lack of electrocardiographic documentation in the present literature to support this successful intervention. As of 2001, 128 cases of CC had been reported to the U.S. CC Registry.2 Although CC has been reported in patients ranging in age from 3 months to 45 years, it occurs most commonly in children age 4 to 16 years; only 22% of cases occur in persons over age 18 years. According to the data collected by the U.S. CC Registry, 87% of those affected are white and 95% are male. Of the 128 reported cases, 62% occurred during organized competitive sports (eg, baseball, softball, lacrosse, football, hockey, karate), and 38% occurred during normal daily activities or recreational sports.2 In most instances, a baseball or softball traveling at an estimated speed of 30 to 50 mph was the object inflicting the trauma.4

Because of the high mortality rate in CC, evaluation of patients with CC has been limited mainly to postmortem
studies. However, in CC survivors, cardiac enzyme levels are usually within normal ranges and do not signify myocardial necrosis. The rise in cardiac enzyme levels that occurred in our patient was likely due to myocardial injury from both the trauma and the cardioversion; these levels returned to normal within 60 hours of the event (Figure 3). Echocardiography in CC survivors almost universally demonstrates an anatomically and functionally normal heart. In addition, angiography performed in CC survivors generally demonstrates normal cardiac and coronary artery anatomy. The only consistently reported abnormality in both survivors and nonsurvivors has been the presence of ventricular fibrillation and/or asystole on the presenting electrocardiogram. Survivors commonly show ST-segment elevation in leads V1 to V3. Complete heart block, left bundle branch block, and idioventricular escape rhythms also may be seen, but these generally last only a few days.5

Various pathophysiologic mechanisms for the cardiac insult suffered during this form of chest wall trauma have been proposed. The most widely accepted theory is that the precordial impact during at-risk phases of the cardiac cycle (most likely during the period of repolarization) result in activation of an inactive potassium channel, leading to ventricular fibrillation.6 Studies using swine models of CC have demonstrated the importance of critical timing and location of blunt chest trauma required to induce ventricular fibrillation and sudden death. These studies have found that ventricular fibrillation was triggered when impact occurred over the anatomic position of the heart, most often over the center of the left ventricle. In this model, resultant cardiac abnormalities have included nonsustained polymorphic ventricular tachycardia, ST segment elevation, transient complete heart block, left bundle branch block, and left ventricular wall motion abnormalities.7,8 Some investigators believe that this explanation is too straightforward and that the mechanism of sudden death due to CC is more complex, including components of coronary artery vasospasm, myocardial contusion, or both.9 This complex theory attempts to provide a rationale for those efforts that have produced successful resuscitation. The biochemical evidence of cardiac muscle injury in the child described in this report, as evidenced by his elevated serum troponin-I level, is slightly higher than has been reported in survivors of out-of-hospital cardiac arrest (mean time of CPR was 6 minutes) that did not result from CC, but lower than nonsurvivors, who received an average of 34 minutes of CPR.10 The extent of myocardial injury occurring from the initial insult from the baseball and that occurring from the subsequent CPR and defibrillation cannot be separated in this case.

Unfortunately, the general survival rate in CC is 16%. With resuscitative measures initiated within 3 minutes of the event, survival has approached 25%. Cases in which resuscitative efforts (either CPR alone or a combination of CPR and AED) were delayed for more than 3 minutes had a survival rate of only 3%.2 These dismal survival rates demonstrate that more effective first-responder therapy is needed to improve survival in these previously healthy athletes.

Based on a swine model of CC, the practice of making AEDS readily available and training personnel in their proper use may have an advantageous effect on outcome.3 More than 90% of NCAA Division I universities already have AEDs at selected sporting venues and athletic facilities.11 In 35 cases where an AED was used to treat of sudden cardiac arrest, 77% of the individuals were older nonstudents, and a successful resuscitation rate of 71% was realized after delivery of effective shocks.11 Five cases of cardiac arrest occurring in intercollegiate athletes were unsuccessfully resuscitated, but it is unknown whether ventricular fibrillation was present in these cases. The average cost of the AEDs in use was $2,500, and the cost per life of those immediately resuscitated was $49,000. Conversely, the cost per life-year gained was estimated as $10,000 to $22,000. A favorable incremental cost-effectiveness ratio is associated with the policy of placing AEDs in high schools.12

In the child described in this report, trained paramedics applied the AED. Thus it is unknown whether this child would have been successfully resuscitated had the coaching staff or untrained bystanders delivered this therapy. This question has not yet been studied in children sustaining cardiac arrest, but in a study using an adult manikin, naïve bystanders were able to deliver a resuscitative shock within 1.5 to 3.5 minutes, varying depending on the AED–user interface.13 Another recent study has demonstrated the successful use of an AED by untrained sixth-grade children,14 suggesting that the BLS-trained coaching staff in our case likely would have been able to deliver a successful defibrillation shock.

Other suggestions have been made on ways to decrease the incidence of CC. The National Athletic Trainer Association has suggested that children involved in sports
involving projectile objects wear chest protector equipment. Unfortunately, however, 28% of reported cases of CC occurred despite the use of chest protectors, and animal models have yielded no evidence that commercially available chest protectors can significantly reduce the likelihood of ventricular fibrillation. Using softer “safety” baseballs in Little League has also been suggested, because the risk of sudden cardiac death appeared to be reduced (although not abolished) in an animal model of CC.

CC is a rare, yet devastating event that can result from projectile-related chest trauma, at any time and to any child, including previously healthy children. We suggest that communities and school districts reexamine the need for accessible AEDs and CPR-trained coaches and instructors at organized sporting events for children. How to determine the cost-effectiveness of this therapy for each community and school district, where to place the AEDs for maximal effectiveness, and at which sporting events they should be present deserve formal study.

REFERENCES