CASE REPORT

Neurologic Recovery Following Prolonged Out-of-Hospital Cardiac Arrest With Resuscitation Guided by Continuous Capnography

Roger D. White, MD; Bruce W. Goodman, CCEMT-P; and Mary A. Svoboda, RN

A 54-year-old man with no known cardiac disease collapsed outdoors in a small rural community. The cardiac arrest was witnessed, and immediate cardiopulmonary resuscitation was begun by a bystander and a trained first responder who was nearby. The patient was moved into a building across the street for continued resuscitation. First responders arrived with an automated external defibrillator, and ventricular fibrillation was documented. First responders delivered 6 defibrillation shocks, 4 of which transiently restored an organized electrocardiographic rhythm but with no pulse at any time. Additional emergency medical services personnel from nearby communities and an advanced life support (ALS) flight crew arrived. The flight crew initiated ALS care. The trachea was intubated, ventilation controlled, and end-tidal carbon dioxide tension continuously monitored. Antiarrhythmic and inotropic drugs were administered intravenously. An additional 6 shocks were delivered using the ALS defibrillator. End-tidal carbon dioxide measurements confirmed good pulmonary blood flow with chest compressions, and resuscitation was continued until a stable cardiac rhythm was restored after 96 minutes of pulselessness. The patient was transported by helicopter to the hospital. He was in cardiogenic shock but maintained a spontaneous circulation. Coronary angiography confirmed a left anterior descending coronary artery thrombotic occlusion that was treated successfully. After hospital admission, the patient required circulatory and ventilatory support and hemodialysis for acute renal failure. He experienced a complete neurologic recovery to his pre-cardiac arrest state. To our knowledge, this is the longest duration of pulselessness in an out-of-hospital arrest with a good outcome. Good pulmonary blood flow was documented throughout by end-tidal carbon dioxide measurements.

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AED = automated external defibrillator; ALS = advanced life support; CPR = cardiopulmonary resuscitation; VF = ventricular fibrillation

Prolonged resuscitation attempts in patients with cardiac arrest are technically difficult and usually futile. There is no documentation in the literature describing resuscitation attempts in an out-of-hospital cardiac arrest longer than 60 minutes with a successful patient outcome.

We describe an out-of-hospital cardiac arrest without prior hypothermia in which the patient made a complete neurologic recovery after 96 minutes of sustained pulselessness caused by recurrent ventricular fibrillation (VF). To our knowledge, this report describes the longest duration of continuous cardiopulmonary resuscitation in a normothermic person experiencing an out-of-hospital cardiac arrest that resulted in a good clinical outcome.

REPORT OF A CASE

After completing a daily workout exercise regimen in a small community gymnasium, a 54-year-old man returned to his home and began preparing dinner. Realizing that he needed a propane tank for his grill, he proceeded to a grocery store, where he collapsed from cardiac arrest just outside the door. The arrest was witnessed, and prompt cardiopulmonary resuscitation (CPR) was initiated by a bystander and a nearby CPR-trained first responder. In the next 4 to 5 minutes, additional first responders arrived with an automated external defibrillator (AED) (Zoll EMS Pro, Zoll Medical Corp, Chelmsford, MA). The AED was attached and VF documented (Figure 1).

These events unfolded on a cold day in January 2011 with an outside temperature of –4°C. The patient was moved out of the cold into a fire hall garage across the street from the site of arrest for continued resuscitation. While a Mayo Clinic medical transport helicopter and flight crew were en route, the first responders continued CPR and, during the next 24 minutes, 6 rectilinear biphasic waveform defibrillation shocks with escalating energy (120-200 J) were delivered at intervals separated by CPR. Four of the 6 shocks terminated VF transiently, with recurrence of VF from 11 to 420 seconds after each shock. At no time were the first responders able to palpate a pulse, despite the transient presence of an organized electrocardiographic rhythm after 4 of the shocks.

The flight crew arrived on the scene 34 minutes after receiving the 911 call. By this time, several other emergency medical services agencies from neighboring communities had arrived to assist, and thereafter chest compressions and ventilations were rotated among all the personnel. After a period of uninterrupted CPR, the flight crew attached their advanced life support (ALS) monitor-defibrillator (Zoll M Series CCT defibrillator). Ventricular fibrillation was ob-

From the Department of Anesthesiology (R.D.W.), Division of Cardiovascular Diseases (R.D.W.), Department of Emergency Medicine (R.D.W.), and Mayo Clinic Medical Transport (R.D.W., B.W.G., M.A.S.), Mayo Clinic, Rochester, MN.

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Individual reprints of this article are not available. Address correspondence to Roger D. White, MD, Department of Anesthesiology, Mayo Clinic, 200 First St SW, Rochester MN 55905 (white.roger@mayo.edu).

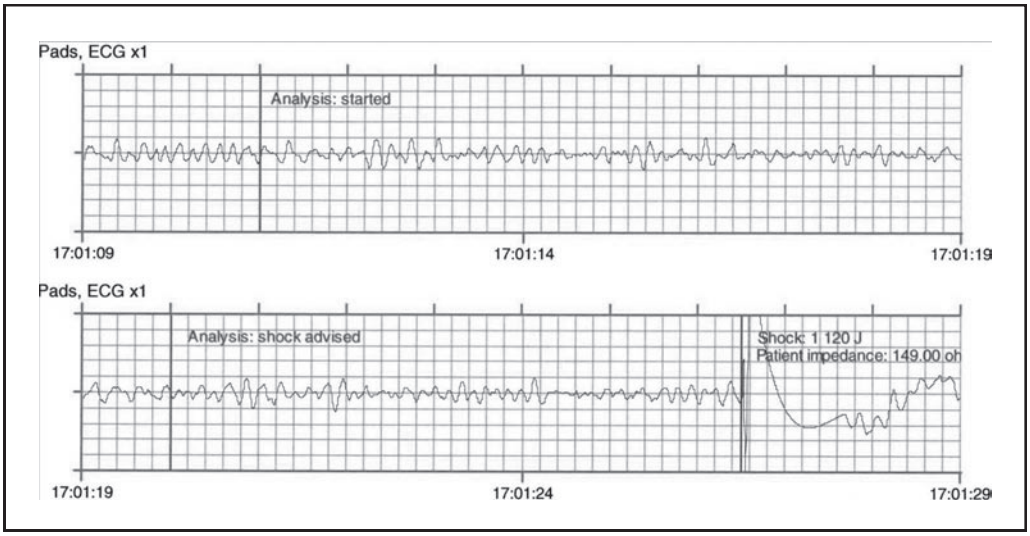

FIGURE 1. Initial electrocardiogram (ECG) showing ventricular fibrillation and the first shock from the first responder automated external defibrillator. Ventricular fibrillation persisted after the shock.

served; the trachea was intubated, ventilation provided by a bag-valve-tube device, intravenous access obtained, CPR continued, and the first defibrillation shock from the ALS defibrillator delivered. The ALS defibrillator also delivered rectilinear biphasic waveform shocks. An end-tidal carbon dioxide sensor (Respironics Novametrix, Wallingford, CT) was attached to the endotracheal tube and, throughout the remainder of the resuscitation, end-tidal carbon dioxide tension was continuously monitored. This measurement is an objective indicator of pulmonary and therefore systemic blood flow during CPR[1,2] and of the efficacy of chest compressions.[3] It has been used to determine the likelihood of a successful resuscitation in an out-of-hospital cardiac arrest.[4,5]

Throughout the following 41 minutes, 5 mg of epinephrine, 300 mg of amiodarone, 1 mg of atropine, and 200 mg of lidocaine were administered intravenously. Despite the long period of arrest and resuscitation, the dose of epinephrine was limited to 5 mg because of documentation of good perfusion pressure by end-tidal carbon dioxide measurements and because of concern that further doses of epinephrine might perpetuate the recurrence of VF. Five defibrillation shocks interspersed with CPR were administered, 3 of which transiently restored an organized but pulseless rhythm for up to a maximum of 40 seconds. Throughout resuscitation, end-tidal carbon dioxide tension was consistently in the 28- to 36-mm Hg range during VF. These levels were consistent with good chest compression–generated blood flow (Figure 2), justifying continuation of the resuscitation with the hope of a good outcome. Continued rotation of rescuers performing chest compression ensured avoidance of rescuer fatigue. During chest compressions after the third ALS shock, a pulseless wide QRS complex rhythm was restored. The fourth shock changed the amplitude of this rhythm, which then degenerated back into VF. After the fifth ALS shock, with VF still present, a decision was made to administer 300 mg of additional amiodarone, rather than the protocol-authorized 150 mg. Following continued CPR, the sixth shock was delivered. After this shock, the end-tidal carbon dioxide tension was 37 mm Hg, and an organized rhythm was present (Figure 3). Although a pulse could not yet be palpated, it was assumed that a spontaneous circulation had resumed, and CPR was discontinued. The time from collapse to restoration of a sustained spontaneous circulation using this end point was 96 minutes. After several minutes, with sustained end-tidal carbon dioxide tensions observed on the monitor screen, an organized electrocardiographic rhythm resumed, and carotid and femoral pulses were palpated.

With continued sustained spontaneous circulation, the patient was placed into the helicopter and transported to Saint Marys Hospital in Rochester, MN. The flight took approximately 20 minutes. From the time of collapse to restoration of pulses, a total of 12 defibrillation shocks were delivered: 6 from the first responder AED and 6 with the ALS defibrillator.

On admission of the patient to the emergency department, a 12-lead electrocardiogram showed a sinus tachycardia, a nonspecific intraventricular conduction block, and ventricular premature complexes (Figure 4). After additional amiodarone was administered in the emergency department (for an episode of nonsustained ventricular

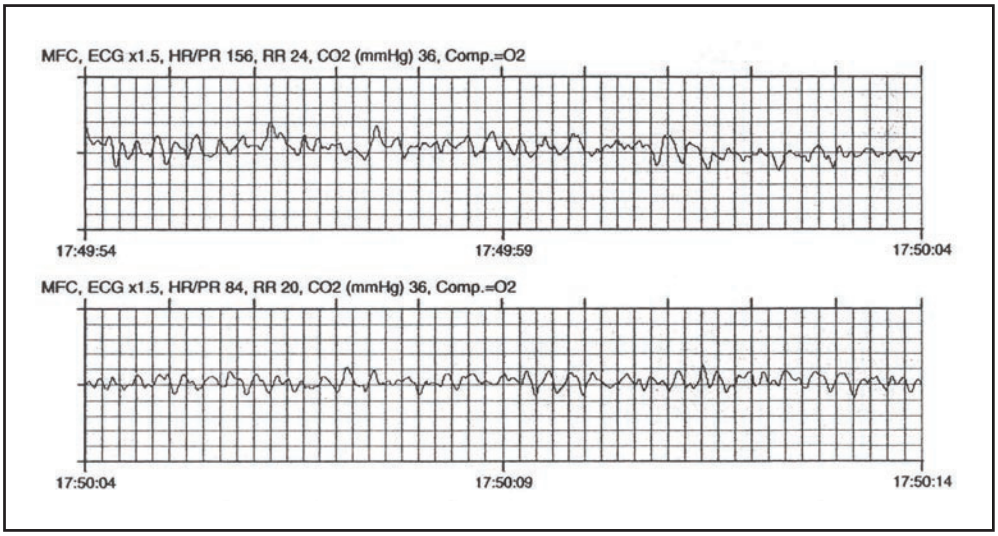

FIGURE 2. Electrocardiogram (ECG) showing ongoing ventricular fibrillation while cardiopulmonary resuscitation was in progress. The end-tidal carbon dioxide (CO_2) tension was 36 mm Hg.

tachycardia) and the patient was stabilized, he was urgently transferred to the cardiac catheterization laboratory, where a 100% occlusion of the mid-left anterior descending coronary artery with thrombus was confirmed. Percutaneous transluminal coronary angioplasty, stent deployment, and thrombectomy were performed successfully (Figure 5). Multivessel coronary artery disease was present, with chronic right coronary artery and obtuse marginal artery occlusions. Because the patient was experiencing acute pulmonary edema and cardiogenic shock, an intra-aortic balloon pump was inserted, and he was returned to the coronary care unit. Mechanical ventilation, begun during helicopter transport, was continued. Transthoracic echocardiography revealed an estimated left ventricular ejection fraction of 30% to 35%. Therapeutic hypothermia was not used because of hemodynamic instability that required an intra-aortic balloon pump and inotropic support. During the next several days, hemodynamic factors stabilized, pulmonary edema resolved, and acute renal failure, treated with continuous venovenous hemodialysis, also resolved.

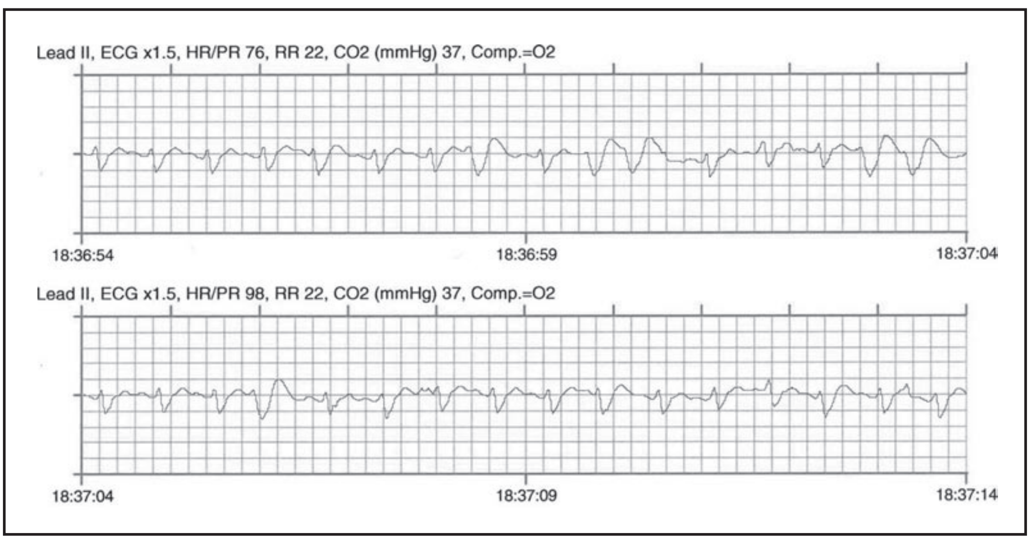

FIGURE 3. After the sixth shock from the advanced life support defibrillator, an electrocardiogram (ECG) showed return of an organized rhythm with an end-tidal carbon dioxide (CO_2) tension of 37 mm Hg.

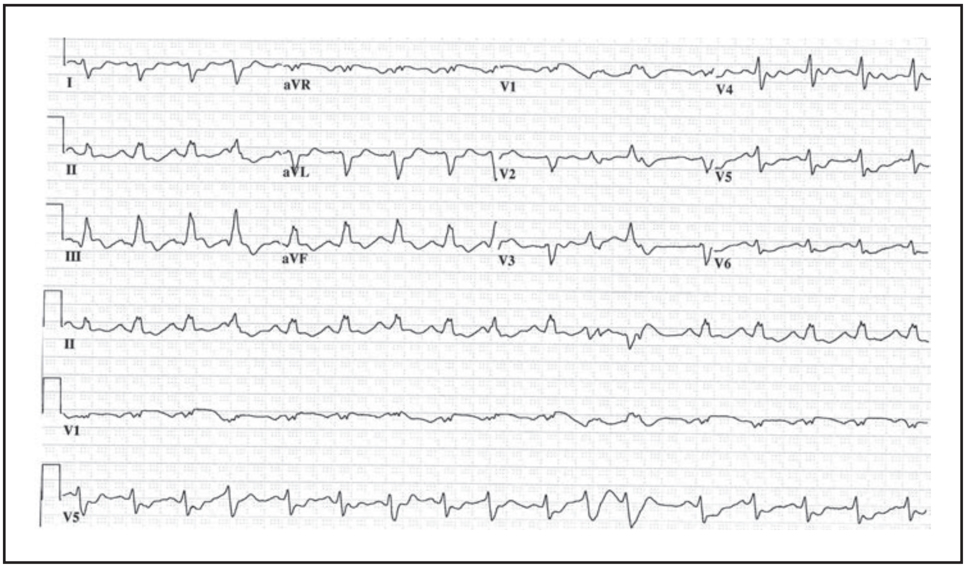

FIGURE 4. A 12-lead electrocardiogram obtained after admission of the patient to the emergency department.

On the 10th day after hospital admission, the patient was discharged and was fully intact neurologically; 11 weeks after discharge, he underwent an elective coronary artery bypass operation. Before the patient was discharged, the calculated left ventricular ejection fraction was 44%.

DISCUSSION

In our patient, recurrent VF after occlusion of the left anterior descending coronary artery resulted in 96 minutes of life-sustaining CPR; efficacy was documented throughout with physiologically normal end-tidal carbon dioxide tensions. Recurrent VF was ultimately terminated with an additional dose of amiodarone followed by another shock. Despite the extremely long period of cardiac arrest with no return of a pulse until the end, provision of life-sustaining CPR throughout enabled a complete neurologic recovery as determined by clinical examination by numerous physicians. To date, the patient has not been referred for formal neurologic assessment because consulting physicians concluded that his postresuscitation neurologic recovery was complete and his neurologic and cognitive function had returned to pre-arrest baseline.

A previous case report described resuscitation of 107 minutes with patient survival. The patient had been submerged in cold water for the preceding 48 minutes, and body temperature was 26.2°C after retrieval from the cold water.[6] The accidental hypothermia provided brain protec-

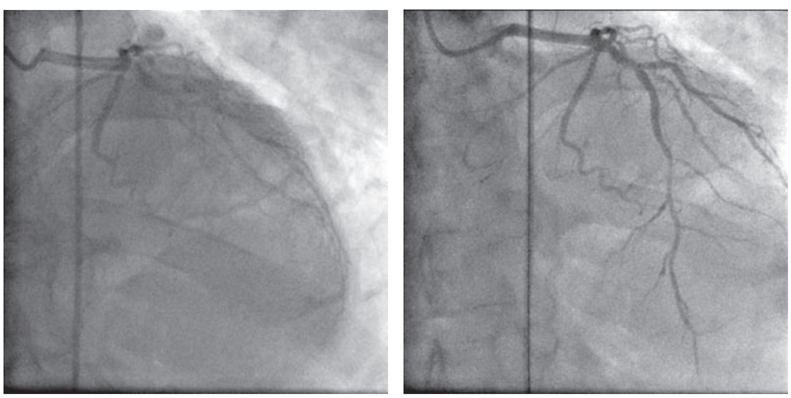

FIGURE 5. Left, Coronary angiogram obtained before intervention showing complete occlusion of the left anterior descending coronary artery. Right, Coronary angiogram obtained after intervention showing that the reopened left anterior descending coronary artery has excellent downstream flow.

tion during the submersion and most likely contributed to the good outcome.

A retrospective study reviewed a 5-year experience with prolonged resuscitation efforts in the cardiac catheterization laboratory with use of a mechanical device to maintain chest compression.[7] Of 38 patients, 11 survived to hospital discharge, with a mean treatment time with the mechanical compression device of 28.15 minutes (standard error of the mean, ±3.4 minutes; range, 1-90 minutes).

Provision of chest compressions during CPR is a physically demanding intervention and is a cause of inadequate CPR performance. The 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care emphasize the need for better CPR performance, in particular the need for minimally interrupted chest compressions of adequate depth and rate and the potential value of monitoring end-tidal carbon dioxide tension during CPR to guide optimization of compressions to detect fatigue in rescuers.[8,9]

CONCLUSION

In our case, with the latest resuscitation guidelines performed optimally and the ongoing efficacy of the resuscitators' performance documented in real time, the outcome is far beyond historical expectations. As such, the results from our single patient demonstrate the promise of ongoing research on ALS techniques, widespread education and training of those who use the techniques, optimal application of the techniques, and use of technology to validate in real time the efficacy of resuscitation interventions.

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