Coronary Perfusion Pressure during Cardiopulmonary Resuscitation

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Currently, there is no way to measure the effectiveness of cardiopulmonary resuscitation in humans. The literature suggests that minimum aortic diastolic and estimated coronary perfusion pressures during cardiopulmonary resuscitation (CPR) in the animal model correlate with higher resuscitation rates. Six patients were studied during CPR to determine the arterial diastolic and estimated coronary perfusion pressures (arterial minus right atrial diastolic pressures). Mean arterial pressures were 27/11 mm Hg, central venous pressures were 32/10 mm Hg, and the mean estimated coronary perfusion pressure was only 1 mm Hg. None of the six patients survived. This study demonstrates that the techniques of measuring hemodynamic values during CPR is practical. Poor estimated coronary perfusion pressures were obtained from the six patients studied. This study should be extended to include a large number of patients to determine whether these hemodynamic parameters can be used as prognostic indicators of successful resuscitation in humans. (Am J Emerg Med 1985; 3:11–14)

Presently, there is no satisfactory means to assess the adequacy of closed-chest massage in resuscitating humans in cardiac arrest. Several commonly used techniques for measuring the effectiveness of cardiopulmonary resuscitation (CPR) are flawed in both theory and practice. Redding[1] has shown that adequate aortic diastolic pressures are necessary for successful resuscitation of dogs. Other investigators have found that the aortic diastolic and estimated coronary perfusion pressures could be used as prognostic indicators of survival in animals.[2–4] However, few studies on humans have been attempted. Therefore, this study was undertaken to: 1) determine whether it is practical to measure the arterial diastolic and estimated coronary perfusion (arterial minus right atrial diastolic) pressures in humans undergoing cardiopulmonary resuscitation; 2) determine the arterial diastolic and estimated coronary perfusion pressures in a sample of humans undergoing cardiopulmonary resuscitation; 3) serve as a preliminary study in attempting to correlate aortic diastolic and estimated coronary perfusion pressures with survival of cardiac arrest in humans.

MATERIALS AND METHODS

After an institutional review board's approval, adult patients admitted to an emergency department with a nontraumatic cardiac arrest were studied. All patients received advanced life support in the field, including oxygen, endotracheal intubation, monitoring, and intravenous medications as necessary. Upon presentation to the emergency department, each patient was placed in a resuscitation room. Chest compressions and ventilation were performed by the Thumper® (Michigan Instruments, Inc., Grand Rapids, Michigan). Chest compressions were performed at a rate of 60 per minute with a 50% duty cycle. Ventilation was powered by 100% oxygen and a ventilation pressure of 30 cm H_2O. Breaths were interposed with each fifth chest compression, and continuous electrocardiographic monitoring was maintained. Each patient had a central venous line placed through either the right subclavian vein or the right internal jugular vein, per ACLS protocol.[5] Simultaneously, a radial artery cutdown was performed and the radial artery cannulated with a 20-gauge catheter. Each line was attached to pressure transducers and a monitor (Tektronix, Beaverton, Oregon) with printout capabilities. After calibrating the monitor at zero, per manufacturer's specifications, central venous and arterial pressure waveforms were simultaneously recorded. Arterial and central venous systolic and diastolic pressures were recorded continuously until resuscitative efforts were terminated. At least four points on the simultaneous central venous and arterial pressure waveforms were randomly selected. Systolic and diastolic values for the central venous and arterial pressure waveforms were measured at each of the four points and averaged. Estimated coronary perfusion pressure was calculated as arterial mid-diastolic pressure minus central venous mid-diastolic pressure.

RESULTS

Six patients were studied, four men and two women, with an average age of 70.8 years. The systolic, diastolic, and estimated coronary perfusion pressures for

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TABLE 1. Hemodynamic Pressures in Six Patients During CPR

	Arterial (systolic/diastolic)	Central Venous (systolic/diastolic)	Coronary Perfusion Pressure (mm Hg)*
Patient 1	34/19	37/19	0
Patient 2	61/29	55/15	14
Patient 3	32/11	36/10	1
Patient 4	14/0	36/10	−10
Patient 5	16/7	12/4	3
Patient 6	7/0	17/7	−7
Mean ± SD	27 ± 18/11 ± 10	32 ± 14/10 ± 5	1

* Estimated coronary perfusion pressure is calculated as arterial diastolic minus central venous diastolic pressure.

the six patients are presented in Table 1. Overall, the mean arterial pressures were 27/11 mm Hg and central venous pressures of 32/10 mm Hg. Mean estimated coronary perfusion pressure was only 1 mm Hg. None of these six patients survived.

Patient 1. An 80-year-old woman was found unconscious at home and was thought to have been unconscious for approximately 10 minutes. She was in a pulseless idioventricular rhythm and was unresponsive to bicarbonate and epinephrine therapy for 10 minutes in the field and 14 minutes in the emergency department.

Patient 2. A 68-year-old man experienced a witnessed cardiac arrest, and CPR was begun immediately. Paramedics arrived after basic life support had been administered for 10 minutes. They found the victim to be in ventricular fibrillation and administered epinephrine, bicarbinate, bretyllium, and three countershocks in the field. In the emergency department, the patients' rhythm deteriorated into electromechanical dissociation. The patient was unresponsive to epinephrine, bicarbonate, dexamethasone, and calcium chloride.

Patient 3. A 78-year-old man was transported by an EMT unit after an estimated period of unconsciousness of one hour. The patient was in a pulseless idioventricular rhythm and was unresponsive to administration of epinephrine, bicarbonate, atropine, dopamine, pericardiocentesis, and fluid challenge.

Patient 4. A 76-year-old man experienced cardiac arrest as the paramedics arrived. He was in electromechanical dissociation and unresponsive to epinephrine and atropine in the field; bicarbonate, epinephrine, isoproteranol, dopamine, and pericardiocentesis were administered in the emergency department without success.

Patient 5. A 61-year-old man was found to be in ventricular fibrillation by the paramedics. It was unknown how long he had been unconscious. He was treated with epinephrine, bicarbonate, bretyllium, and three countershocks in the field, but did not respond. Treatment in the emergency department included administration of epinephrine, bicarbonate, calcium chloride, atropine, narcan, bretyllium, and multiple countershocks.

Patient 6. A 62-year-old woman had been unconscious for approximately 10–12 minutes. The patient's heart went from ventricular fibrillation to pulseless idioventricular rhythm to asystole. She was unresponsive to treatment with epinephrine, bicarbonate, calcium chloride, and multiple countershocks.

DISCUSSION

No adequate parameters yet exist for measuring the effectiveness of cardiopulmonary resuscitation (CPR) in humans. Several measurements are commonly used, but there are no data to support their validity. The presence of femoral pulses during chest compression is often looked upon as a sign of the adequacy or effectiveness of CPR. However, femoral pulsations, at best, would reflect pulse pressure (systolic minus diastolic pressure), which has not been correlated with successful resuscitation. Similarly, favorable arterial blood gas values have been looked upon by clinicians as evidence of adequate circulation. Recent studies, however, have shown that arterial blood gas values do not seem to correlate with successful resuscitation in animals, and near-normal values may be indicative of poor perfusion.[6] The presence or absence of pupillary reactions to light is sometimes used as an indicator of the degree of cerebral perfusion. This response, however, is nonspecific and is often obscured by therapeutic modalities used during the resuscitation (*e.g.*, atropine, epinephrine).

We believe documentation of effective CPR would be very useful as a guideline for rationally approaching and treating patients in cardiac arrest. Evidence seems to show that critical decisions in resuscitative maneuvers must be accomplished within a period of 15 to 30 minutes if patients are to be resuscitated from cardiac arrest.[7] If effective CPR cannot be obtained promptly with standard advanced cardiac life support techniques, more invasive procedures may be considered.

The role of thoracotomy and internal cardiac massage is undergoing re-evaluation. It has recently been shown in the animal model that open-chest massage may improve the resuscitation rate after 15 minutes of inadequate closed-chest massage.[8] The use of other pharmacological agents, such as phenylephrine or methoxamine, might be better evaluated if specific hemodynamic parameters associated with successful resuscitation could be followed.

Animal studies have shown that some hemodynamic parameters are correlated with successful resuscitation. As early as 1906, Crile and Dolley[9] demonstrated in animals that an aortic diastolic pressure of 30–40 mm Hg was needed for resuscitation. They speculated that this pressure was needed to adequately perfuse the coronary arteries and demonstrated that epinephrine can be useful in raising this pressure. More recently, Redding[1] has shown that when the aortic diastolic pressure can be raised above 40 mm Hg by drugs or maneuvers such as abdominal binding, dogs could be successfully resuscitated from asphyxial arrest. When this diastolic pressure could not be achieved the animals could not be resuscitated. More recently it has been shown that the aortic diastolic and estimated coronary perfusion pressure (aortic minus right atrial diastolic pressure) could be used as a prognostic and therapeutic guideline for resuscitation of dogs in ventricular fibrillation, even after 30 minutes of cardiac arrest.[4] The present study attempts to determine whether these observations from the animal model could be used in improving cardiopulmonary resuscitation in humans.

First, it was determined that in the setting of the University Hospital it is practical to place arterial and central venous catheters to measure pressures in patients suffering cardiac arrest. Although this was not formally documented, we feel both these procedures can be accomplished in less than 5 minutes in the emergency department. The emergency department staff and the pressure transducers, however, must be prepared as soon as the call comes in from the prehospital care system. The second objective of this study was to determine the pressures generated during standard cardiopulmonary resuscitation in humans. In the animal model, it is thought that aortic diastolic pressures of at least 30 to 40 mm Hg must be obtained in order for resuscitation to be successful. None of our six patients were able to exceed this pressure with closed-chest massage and standard advanced cardiac life support treatment, and all six patients died. The data on the estimated coronary perfusion pressure is also very interesting. Two patients had negative estimated coronary perfusion pressures, and the highest pressure obtained was 14 mm Hg. The importance of the estimated coronary perfusion pressure is speculative at best. Ditchey[10] showed that in animals undergoing cardiopulmonary resuscitation, coronary blood flow is highly correlated with the mean aortic minus right atrial pressures. Ralston[3] demonstrated that the diastolic arterial venous pressure difference is directly correlated with heart blood flow and resuscitability in dogs undergoing cardiopulmonary resuscitation. Thus, these low pressures demonstrated in humans undergoing closed-chest massage may be indicative of poor coronary blood flow.

Definite conclusions cannot be made based on the hemodynamic data from this small group of patients. Indeed, this was a select group of patients in cardiac arrest, in that they were still undergoing CPR and unresponsive to initial resuscitative measures by paramedics in the field. Nevertheless, patients who do not respond initially in the field have the worst prognosis. One should be particularly concerned about whether more aggressive resuscitative measures may be efficacious. These data are also consistent with the results of McDonald's[11] study of estimated coronary perfusion pressures during two experimental CPR techniques. Six patients were studied; four had negative estimated coronary perfusion pressures, and none were resuscitated. One patient had an estimated coronary perfusion pressure of 11 mm Hg but did not survive, and the sixth patient had an estimated coronary perfusion pressure of 16 mm Hg and, following a 100-minute resuscitation effort, survived. The present study examines the estimated coronary perfusion pressures during standard CPR according to American Heart Association standards. The third objective of this report was to serve as a preliminary study in attempting to correlate aortic diastolic and estimated coronary perfusion pressures with survival in a large number of humans undergoing cardiopulmonary resuscitation. As the prognosis in this group of patients is poor, studies of large numbers of patients are needed in order to determine whether hemodynamic parameters can indeed be used as prognostic and therapeutic guidelines in resuscitation of humans in cardiac arrest.

SUMMARY

A series of six patients who underwent arterial and central venous catheterization and monitoring during cardiopulmonary resuscitation is described. Measurements of these parameters during cardiac arrest was feasible and potentially useful as a guideline for gauging the effectiveness of cardiopulmonary resuscitation. Arterial diastolic and estimated coronary perfusion pressures were poor in all six patients, and none were resuscitated. Perfusion pressure monitoring during CPR in the emergency department is feasible

and may provide an objective indication for open-chest CPR if zero or negative perfusion pressures are observed.

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