Resuscitation, 23 (1992) 71–76
Elsevier Scientific Publishers Ireland Ltd.

Controversies in Resuscitation

A new proposal of CPR based on coronary perfusion pressure

Joseph Eldor

Mobile Intensive Care Unit, Magen David Adom, Jerusalem (Israel)

(Received December 10th, 1991; accepted December 18th, 1991)

Closed chest massage and tracheal intubation are not enough. The 70% success rate promised by Kouwenhoven 31 years ago is not realised. Coronary perfusion pressure is the main goal. To achieve this a proposal of a combined new CPR is advocated which encompass the following items besides closed chest massage and tracheal intubation: (a) use of high dose methoxamine (instead of epinephrine), (b) use of continuous abdominal pressure (instead of intermittent pressure), (c) unloading the pump, which means no use of any intravenous fluids, and (d) intracardiac injection of medications until restarting of spontaneous circulation.

Key words: coronary perfusion pressure; methoxamine; epinephrine; abdominal compression; pump unloading; intracardiac injection

INTRODUCTION

More than 650 000 people die annually of cardiovascular disease in the United States. More than 50% of these deaths occur prior to arrival at a hospital, usually within a few hours of symptom onset [1].

The first mobile intensive care unit (MICU) was established in 1966 in Belfast, Ireland [2]. Since then MICU have been established all over the world with trained paramedics. In some countries, like Israel, there is also a medical doctor in the MICU team.

However, the history of out-of-hospital resuscitation didn't begin in 1966, or in 1960 with the rediscovery of the closed-chest massage by Kouwenhoven. The first resuscitation was done by the prophet Elisha [3] who used mouth-to-mouth ventilation to resuscitate the child of a Shunammite woman.

This critical article intends to reevaluate the common practice in a more perspective way. Some old practices are compared to new developments. Analysis of the material brings new conclusions.

Correspondence to: Joseph Eldor, Mobile Intensive Care Unit, Magen David Adom, Jerusalem, Israel.

0300-9572/92/$05.00

CORONARY PERFUSION PRESSURE (THE HIDDEN GOAL)

Coronary perfusion pressure (CPP), the aortic to right atrial pressure gradient during the relaxation phase of cardiopulmonary resuscitation (CPR) is the most important factor for a successful resuscitation. This gradient is correlated positively with return of spontaneous circulation and survival [4].

Paradis et al. [5] found that 24 out of 100 patients with cardiac arrest had return of spontaneous circulation. These patients had an initial CPP of 13.4 ± 8.5 mmHg compared to 1.6 ± 8.5 mmHg in the other 76. The maximal CPP was 25.6 ± 7.7 mmHg in those who had return of spontaneous circulation compared to only 8.4 ± 10.0 mmHg in those who did not. Twenty of the 24 patients maintained spontaneous circulation for longer than 1 h and no patient survived to hospital discharge.

The deficiency of coronary blood flow is the main etiologic factor in many instances of cardiac arrest. So, to optimize CPR, CPP must be optimized.

The observation that intrathoracic vascular pressures are nearly equal during CPR suggests that closed-chest resuscitation may be ineffective in delivering blood to the heart itself. Ditchey et al. [6] examined 12 dogs using closed-chest massage after cardiac arrest. Ascending aortic and right atrial pressures were always similar. However, high-compression-force CPR produced small mean pressure differences across the coronary vascular bed (5.6 ± 0.8 mmHg at 140 pounds). Coronary flow was less than 1% of control (pre-arrest) values whenever chest compression force was less than 100 pounds and only 4.3 ± 2.0% of pre-arrest values at 140 pounds.

METHOXAMINE INSTEAD OF EPINEPHRINE

Epinephrine is an important drug in CPR since the study of Crile and Dolley in 1906 [7]. It is an α_1 and α_2 adrenergic agonist and a strong β_1 and β_2 stimulant. However, its efficacy during CPR relies entirely on the α effects [8].

The current recommendation of the American Heart Association is 0.5–1 mg i.v. every 5 min [9].

Gonzales et al. [4] reported that 5 mg doses of epinephrine increased diastolic blood pressure in 10 human patients studied after approximately 1 h of attempted resuscitation [10]. Paradis et al. [11] found an increase in coronary perfusion pressure after 12–14 mg doses of epinephrine administered approximately 45 min following arrest. However, although large doses of epinephrine increase coronary perfusion pressure and flow during CPR, epinephrine also increases myocardial oxygen consumption during ventricular fibrillation [12].

Livesay et al. [13] found that coronary perfusion pressure and flow during open-chest CPR can be increased substantially by either epinephrine or methoxamine (a relatively pure α-adrenergic agonist). However, doses of epinephrine sufficient to raise arterial pressure from 40 to 65 mmHg during constant flow conditions on cardiopulmonary bypass both increased myocardial oxygen consumption and decreased total and subendocardial myocardial blood flow during ventricular fibrillation. Methoxamine had none of these adverse effects.

CONTINUOUS ABDOMINAL PRESSURE (INSTEAD OF INTERMITTENT PRESSURE)

Nieman et al. [14] have done several studies with abdominal compression and CPR in animals. Aortic pressure and right atrial pressure, both systolic and diastolic, were better with abdominal binding than without.

Redding [15] reported improved circulation restored, return to consciousness and survival, in dogs with an abdominal binder inflated to 150–200 Torr, compared with CPR without abdominal compression. Survival was 7% without abdominal compression in 24 h, and 60% with abdominal compression.

Mahoney and Mirick [16] randomised 136 patients prospectively with refractory prehospital cardiac arrest into patients who received a pneumatic anti-shock garment (PASG) and no-PASG groups. The resuscitation and discharge without PASG were 21% and 4%, respectively, and with PASG were 33% and 9%, respectively. In pulseless idioventricular rhythm the rates were 0% and 0% without PASG and 35% and 9% with PASG.

Using the PASG, there is an increase in the blood volume in the upper half of the body, produced by increased vascular resistance in the lower half. However, this device which is suitable for hemorrhagic shock is not so for cardiac arrest.

In the arrested heart there is a need to reduce the preload and to raise the afterload, in order to improve the CPP.

UNLOADING THE PUMP INSTEAD OF OVERLOADING

Volume loading, by filling venous capacitance vessels, raises right atrial as well as aortic pressures, but not coronary perfusion pressure. By increasing cerebral blood volume there is also an increase in intracranial pressure during CPR.

Ditchey and Lindenfeld [17] found that mean ascending aortic-right atrial difference produced by CPR decreased from 9.8 ± 2.7 mmHg immediately before to 4.0 ± 1.4 mmHg immediately after volume loading in dogs. This resulted primarily from a disproportionate increase in right atrial pressure (relative to aortic pressure) during the relaxation phase of each cycle chest compression.

In order to reduce the preload it is suggested to use four limb's tourniquets, so reducing the effective cardiovascular volume. Together with the abdominal binder there will be a rise in the afterload more than in the preload. So, the closed-chest massage will pump blood against a great resistance with increase in the aortic diastolic pressure more than the right atrial pressure.

CLOSED-CHEST MASSAGE AND TRACHEAL INTUBATION ARE NOT ENOUGH

Boehm [18] in 1878 was the first person to investigate external cardiac massage compression to resuscitate cats after cardiac arrest from potassium salts, chloroform and asphyxia. However, it took 82 years until Kouwenhoven, Jude and Knickerbocker's report [19] of the successful use of closed-chest cardiac massage in 20 patients with 70% overall survival. They were so enthusiastic to write 'Anyone, anywhere, can now initiate cardiac resuscitation procedures. All that is needed are two hands.' All their cases were within-hospital cases, mostly on the operating table.

Out of hospital cardiac arrests are another story. In those cases not only 'two hands' are needed. Published survival rates for out-of hospital cardiac arrests vary widely. More than two decades have passed since Pantridge introduced the mobile intensive care unit (MICU) in Belfast, Ireland [20]. In a survey of 29 cities in eight countries from 1967 to 1988 there were reported discharge rates of from 2 to 25% for all cardiac rhythms and 3–33% for ventricular fibrillation [21].

Not every victim of cardiac arrest is reached in the first 5 min of its occurrence. Closed chest massage and ventilation, preferably through an endotracheal tube are only the first lines of resuscitation. Of course, open chest cardiac massage is still superior, but less practiced [22].

INTRACARDIAC INJECTION, INSTEAD OF ANYWHERE ELSE

Peter Safar [23] has written that 'the blind intracardiac injection of drugs is not recommended during closed chest CPR, as it may produce pneumothorax, injury to a coronary artery and prolonged interruption of external cardiac compression.' However, he continued, 'during open chest cardiac resuscitation, on the other hand, intracardiac injection is safe and effective if performed under direct vision. Epinephrine, antidysrhythmic agents and calcium have been effective when given into the left cardiac ventricle, in about one half of the i.v. doses'.

It seems that there is a discrepancy between these two recommendations. If it is safe and effective by the direct approach, why not improve the indirect approach to this degree. Chen Hao-Hui [24] prefer to inject at a site just to the left of the sternal margin in the 4th or 5th intercostal space. No pneumothoraces were found in patients in whom this puncture site was used.

The distance from the left margin of the sternum to the internal mammary artery ranged in 28 males from 1.25 to 1.80 cm and in 12 females from 0.95 to 1.25 cm with a mean value of 1.48 cm [24].

The use of intracardiac injection of epinephrine to restore heart action has been advocated for years [25] before 1960 ('the year of Kouwenhoven et al.'). It is illogical to exclude this immediate way of resuscitation for one article which promised a 70% success rate.

Davison et al. [26] evaluated 53 patients who received 147 intracardiac injections during CPR. Pericardial effusion was noted in six of 17 echocardiograms and a hemopericardium found in eight of 28 autopsies. Cardiac tamponade was not observed. A pneumothorax developed in one patient. None of the autopsies disclosed coronary artery or ventricular lacerations.

Amey et al. [27] found no more complications in a group of patients who received intracardiac medication in the prehospital area by paramedics than in the control group.

In conclusion, the combined new CPR means — besides the usual CPR of closed chest massage and tracheal intubation — continuous abdominal pressure, four limb's tourniquets, and intracardiac injection of methoxamine until restoration of spontaneous circulation.

After return of spontaneous circulation is another story.

REFERENCES

1 American Heart Association and National Research Council, Standards for Cardiopulmonary Resuscitation (CPR) and emergency cardiac care (ECC), J. Am. Med. Assoc. (Suppl.), 227 (1974) 833–868.
2 J.F. Pantridge, Pre-hospital coronary care, Br. Heart J., 36 (1974) 233–237.
3 2 Kings 4: 34–35.
4 K.B. Kern, G.A. Ewy, W.D. Voorhees, C.F. Babbs and W.A. Tacker, Myocardial perfusion pressure: a predictor of 24-hour survival during prolonged cardiac arrest in dogs, Resuscitation, 16 (1988) 241–250.
5 N.A. Paradis, G.B. Martin, E.P. Rivers, M.G. Goetting, T.J. Appleton, M. Feingold and R.M. Nowak, Coronary perfusion pressure and the return of spontaneous circulation in human cardiopulmonary resuscitation, J. Am. Med. Assoc., 263 (1990) 1106–1113.
6 R.V. Ditchey, J.V. Winkler and C.A. Rhodes, Relative lack of coronary blood flow during closed-chest resuscitation in dogs, Circulation, 66 (1982) 297–302.
7 G.W. Crile and D.H. Dolley, Experimental research into resuscitation of dogs killed by anesthetics and asphyxia, J. Exp. Med., 8 (1906) 713.
8 C.W. Otto and R.W. Yakaitis, The role of epinephrine in CPR. A reappraisal, Ann. Emerg. Med., 13 (1984) 840.
9 Standards and guidelines for cardiopulmonary resuscitation (CPR) and emergency cardiac care (ECC), J. Am. Med. Assoc., 255 (1986) 2905.
10 E.R. Gonzales, J.P. Ornato, A.R. Garnett et al., Dose-dependent vasopressor response to epinephrine during CPR in human beings, Ann. Emerg. Med., 18 (1989) 920.
11 N.A. Paradis, G.B. Martin, E.P. Rivers et al., High-dose epinephrine and coronary perfusion pressure during cardiac arrest in human beings (abstract), Ann. Emerg. Med., 18 (1989) 478.
12 R.V. Ditchey and J. Lindenfeld, Failure of epinephrine to improve the balance between myocardial oxygen supply and demand during closed-chest resuscitation in dogs, Circulation, 78 (1988) 382–389.
13 J.J. Livesay, D.M. Follette, K.H. Fey, R.L. Nelson, E.C. DeLand, R.J. Barnard and G.D. Buckberg, Optimizing myocardial supply/demand balance with alpha-adrenergic drugs during cardiopulmonary resuscitation, J. Thorac. Cardiovasc. Surg., 76 (1978) 244–251.
14 J.T. Niemann, J.P. Rosborough, R.A. Niskanen et al., Circulatory support during cardiac arrest using a pneumatic vest and abdominal binder with simultaneous high pressure airway inflation, Ann. Emerg. Med., 13 (1984) 767–770.
15 J.S. Redding, Abdominal compression in cardiopulmonary resuscitation, Anesth. Analg., 50 (1972) 668–675.
16 B.D. Mahoney and M.J. Mirick, Efficacy of pneumatic trousers in refractory prehospital cardiopulmonary arrest, Ann. Emerg. Med., 12 (1983) 8–12.
17 R.V. Ditchey and J. Lindenfeld, Potential adverse effects of volume loading on perfusion of vital organs during closed-chest resuscitation, Circulation, 69 (1984) 181–189.
18 J.W. Pearson, Historical and Experimental Approaches to Modern Resuscitation, Charles C. Thomas, Springfield, IL, 1965, pp. 1–93.
19 W.B. Kouwenhoven, J.R. Jude and G.G. Knickerbocker, Closed-chest cardiac massage, J. Am. Med. Assoc., 173 (1960) 1064–1067.
20 J.F. Pantridge and J.S. Geddes, A mobile intensive care unit in the management of myocardial infarction, Lancet, ii (1967) 271–273.
21 M.S. Eisenberg, B.T. Harwood, R.O. Cummins, R. Reynolds-Haertle and T.R. Hearne, Cardiac arrest and resuscitation: A tale of 29 cities, Ann. Emerg. Med., 19 (1990) 179–186.
22 J. Eldor, D.Z.N. Frankel and J.T. Davidson, Open chest cardiac massage: A review, Resuscitation, 16 (1988) 155–162.
23 P. Safar, Cardiopulmonary Cerebral Resuscitation, World Federation of Societies of Anaesthesiologists, 1981, pp. 97–98.
24 Chen Hao-Hui, Closed-chest intracardiac injection, Resuscitation, 9 (1981) 103–106.

25 J.W. Pearson and J.S. Redding, Epinephrine in cardiac resuscitation, Am. Heart J., 66 (1963) 210–214.
26 R. Davison, V. Barresi, M. Parker, S.N. Meyers and J.V. Talano, Intracardiac injections during cardiopulmonary resuscitation: A low risk procedure, J. Am. Med. Assoc., 244 (1980) 1110–1111.
27 B.D. Amey, E.E. Harrison, E.J. Straub and M. McLeod, Paramedic use of intracardiac medication in prehospital sudden cardiac death, J. Am. Coll. Emerg. Physicians 7 (1978) 130–134.