Back from Irreversibility: Extracorporeal Life Support for Prolonged Cardiac Arrest

Massimo Massetti, MD, Marine Tasle, MD, Olivier Le Page, MD, Ronan Deredec, MD, Gerard Babatasi, MD, Dimitrios Buklas, MD, Sylvain Thuaudet, MD, Pierre Charbonneau, MD, Martial Hamon, MD, Gilles Grollier, MD, Jean Louis Gerard, MD, and André Khayat, MD

Departments of Thoracic and Cardiovascular Surgery, Anesthesiology, Cardiology, and Emergency and Critical Care Medicine, University Hospital, Caen, France

Background. **The survival of patients after prolonged cardiac arrest is still inadequate. Extracorporeal life support (ECLS) represents an alternative therapeutic method for patients who do not respond to conventional cardiopulmonary cerebral resuscitation. This technology is used to support the circulation of a patient with severe cardiac failure.**

Methods. **Between June 1997 and January 2003, 40 ECLS procedures were performed in patients who presented with refractory cardiac arrest. During external cardiac massage, the patient was connected to an extracorporeal circuit by the insertion of an arterial and venous cannula through the femoral vessels. The extracorporeal circuit included a centrifugal pump and an oxygenator. Mean age was 42 ± 15 years; the average time of external cardiac massage was 105 ± 44 minutes.**

Results. **Once the circulation was restored, 22 patients were disconnected from the extracorporeal circulation because of brain death or multiorgan failure; after 24 hours, among the 18 survivors, 6 were weaned off the pump, 9 were bridged to a ventricular assist device, and 2 patients were directly bridged to cardiac transplantation. Eight patients are alive and without any sequelae at 18 month's follow-up.**

Conclusions. **In prolonged cardiac arrest with failing conventional measures, rescue by extracorporeal support provides an ultimate therapeutic option with a good outcome in survivors. Our results encourage the wider application of ECLS for refractory cardiocirculatory arrest in selected patients. The high rate of neurologic death needs further improvements in the early phase of resuscitation maneuvers.**

(Ann Thorac Surg 2005;79:178–84)

Worldwide experience with cardiopulmonary resuscitation (CPR) has demonstrated that survival to discharge ranged from 8.2% to 22% in hospitalized patients and was below 3% in out-of-hospital patients who experienced cardiac arrest [1–2]. Because of the low survival rate after prolonged CPR, methods that are more aggressive have been suggested to increase success.

Extracorporeal life support (ECLS) refers to a technology that is used to support the circulation of a patient with severe cardiac failure. The physiologic objective is to provide temporary circulatory support to the vital organs and to unload the failing heart as the injured myocardium attempts to recover. Indications for applying rescue ECLS have not been clearly defined; however, guidelines have been established to avoid futile efforts [3–6].

Portable cardiopulmonary bypass (CPB) is a simple and effective system for controlling a patient's circulatory and respiratory functions on an emergency basis until physicians evaluate the cause of the patient's hemodynamic shock and initiate further treatment [8, 9]. Because this technology made consistent progress with miniaturized pumps and circuit biocompatibility, cardiothoracic surgeons and ECLS specialists have renewed their interest in the use of CPB as an emergency resuscitative tool for patients suffering from refractory cardiac arrest. Published series have demonstrated an overall survival rate of between 15% and 60% in this heterogeneous category of patients [4–11]. To evaluate the impact of ECLS on the survival of patients who experienced a prolonged cardiac arrest, we retrospectively analyzed our experience.

Patients and Methods

We reviewed the case histories of all patients treated with emergency CPB for prolonged cardiopulmonary arrest at the University Hospital of Caen between June 1997 and January 2003. Data collection was both retrospective and concurrent. The tracking of each patient's clinical course during the hospitalization was recorded. Vascular, neurologic, hemorrhagic, renal, and perfusion system complications were documented. We selected patients whose conditions leading to CPR were thought to be of cardiac origin. ECLS contraindications included previous irreversible brain damage, terminal malignancy, and age of more than 75 years. Patients receiving ECLS support for weaning from CPB, accidental hypothermia, or for respi-

Accepted for publication June 21, 2004.

Address reprint requests to Dr Massetti, Department of Thoracic and Cardiovascular Surgery, University Hospital, 14033 Caen, France; e-mail: massetti-m@chu-caen.fr.

Published by Elsevier Inc

0003-4975/05/$30.00
doi:10.1016/j.athoracsur.2004.06.095

Abbreviations and Acronyms

ACT = activated clotting time
CA = cardiac arrest
CPB = cardiopulmonary bypass
CPC = cerebral performance categories
CPR = cardiopulmonary resuscitation
ECC = extracorporeal circulation
ECLS = extracorporeal life support
ECM = external cardiac massage
EEG = electroencephalogram
IABP = intraaortic balloon pump
ICU = intensive care unit
PBS = portable bypass system
Tx = transplantation
VAD = ventricular assist device

ratory support were excluded. Briefly, patients were included into the ECLS therapy if they:

- presented with refractory cardiac arrest requiring external cardiac massage;
- could not be returned to spontaneous circulation within 45 minutes;
- received ECLS in the hospital.

In ECLS-supported patients, we selected three groups and analyzed the population data, survival at 24 hours, and weaning from ECLS followed by discharge from the hospital. The group "survival at 24 hours" identified those patients who survived to cardiopulmonary resuscitation-advanced life support and showed no signs of irreversible brain damage.

Device Description

The hardware for emergent cardiopulmonary circulation consisted of a Biomedicus portable bypass system (PBS) (Medtronic, Inc, Minneapolis, MN) incorporating a centrifugal pump console and a water pump system. A preconnected tubing set was attached to a hollow-fiber membrane oxygenator with an integral heat exchanger (Maxima PRF, Medtronic, Inc), a constrained vortex pump chamber, and a flow probe. The ECLS circuit consisted of a closed Carmeda Bioactive Surface-coated circuit of polyvinyl chloride tubing (Medtronic, Inc). Cannulas used were Biomedicus (17F to 25F), according to the size of patients.

Table 1. Clinical Pre-Extracorporeal Life Support Features of Studied Patients

	All Population n = 40	Alive > 24 H n = 18	Discharged from Hospital n = 8
Age (years)	42 ± 15	41.4 ± 17	34.6 ± 15
Sex ratio (F/M)	17:23	8:10	4:4
Out-of-Hospital CA	5	1	1
Known cardiopathy	10	7	1
Awaiting heart tx	4	3	0
IAPB	2	1	1

CA = cardiac arrest; Awaiting heart tx = awaiting heart transplantation; IABP = intraaortic balloon pump.

Table 2. Main Indications for Extracorporeal Life Support

	All Population n = 40	Alive > 24 H n = 18	Discharged from Hospital n = 8
Acute Myocardial Infarction	16	4	2
Cardiomyopathy	4	3	0
Medical Intoxication	6	4	4
Myocarditis	2	2	1
Arrhythmia	4	1	0
Postcardiotomy (early period)	4	2	1
Pulmonary embolism	3	1	0

H = hours.

Cannulation Technique

Once the decision to use ECLS support has been made, the surgeon dissects the femoral vessels to the groin. Meanwhile, the perfusionist assembles a circuit that meets the specific requirements of the patient's size and primes it with Ringer's lactate solution. Heparin 50 UI/kg is administered intravenously to the patient immediately before cannulation of the vessels. Reinjection of a low dose of heparin allows the activated clotting time (ACT) to be kept at between 150 and 180 seconds at full flow.

Cannulation is peripheral (femorofemoral) using Biomedicus Carmeda BioActive Surface-coated extracorporeal membrane oxygenation cannulas (Medtronic, Inc) placed into the femoral vessels through a modified Seldinger technique (surgical cut-down followed by vessel puncture). The distal tip of the arterial cannula is positioned in the common iliac artery or distal abdominal aorta. The distal tip of the venous cannula is placed in the right atrium under echocardiography guidance and confirmed by chest radiography. Limb ischemia used to be the major problem at the beginning of our experience; therefore, perfusion of the distal limb is accomplished with a small 8F catheter. This arterial shunt is instituted between the side port of the arterial cannula and a point located some centimeters distally in the superficial femoral artery.

Successful ECLS is defined as mean blood pressure of at least 60 mm Hg and flows of at least 2.5 L/m^2. The Biomedicus pump rpm is increased to approximately 2,500 rpm maximum or until desired flows are obtained. Vasopressor (norepinephrine) is infused to maintain a mean systemic arterial pressure of more than 60 to 70 mm Hg. Ventricular filling and inotropic support maintain a pulsatile flow through the native heart. The aim is to decompress the left heart and to minimize stasis and therefore the risk of intracardiac clot.

To accomplish mechanical decompression of the left heart, we recently performed an atrial balloon septostomy in one patient. A contralateral femoral vein approach was used in which transseptal puncture, followed